UNITED STATES DEPARTMENT OF AGRICULTURE
U.S. SOIL CONSERVATION SERVICE.
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SMALL FARMSTEAD WATER DEVELOPMENTS IN THE SOUTHWEST

This bulletin has been developed in accordance with Section 3620.2 of the Water Facilities Procedure Manual and is intended to supply general information required in developing the simpler types of farmstead water supplies.

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GLOSSARY OF TERMS

Cylinder	The word cylinder as used in this manual refers to what is technically called a working barrel. The barrel is so constructed that the valves can be pulled through without removing the lead pipes.
Elevation	Elevation, as considered in Table I, designates the vertical distance between the water level from which the water must be pumped to the top of the storage tank in which the water is to be stored.
G.P.D.	This stands for gallons per day.
Lead Pipes	This term is used to designate all underground pipe which leads from the supply pipe to the point of use of the water.
Riser Tubing or Drop Pipe	This term refers to the pipe through which the water is pumpod from the well to an elevation from which it will flow into the storage tank.
Aquifer	A water bearing bed or stratum of earth, gravel, or porous stone.

GENERAL

The development of domestic or farmstead water under the Water Facilities program will, in large part, be governed by the types of water available for development. In general, the main consideration will be the quality and quantity of water available and the daily water requirement. Where springs of reliable capacity are available, their possibilities for the development of water should be investigated. All spring water supplies should be maintained free from pollution. While in most instances wells will probably be the logical development, it may not always be possible to develop wells in the most desirable location, and such developments may require long lead pipes. In some locations neither springs nor wells can be economically developed and here surface supplies may be utilized. This type of development may vary from utilization of perennial streams to utilization of the flood flows of intermittent streams or the run-off from rock ledges and roofs.

In all developments, quality of water should receive first consideration. The development should be so located as to eliminate, as far as possible, any chances of pollution. If there is still danger of pollution, then treatment of water supplies is recommended. Neither springs nor wells are always safe water supplies and they should be checked frequently. All State sanitary regulations should be complied with. Usually farmstead developments will require continued maintenance which should be considered along with the installation costs in determining their feasibility.

The discussions and specifications which follow are not expected to meet all requirements in the great variety of conditions that will be met in Soil Conservation Service Region 8, which includes Arizona, Utah, western Colorado, and all but the eastern tier of counties in New Mexico. However, it is hoped that they will meet average conditions.

At the present time (1941-2) costs are unstable in general, with a trend upward, and it is possible that whatever costs are quoted may be low by the time they are used. When a farmstead water development is planned, it will be well to call in local bidders and get their prices for the particular set of conditions under which the development is planned, and use these costs in preparing a detailed estimate based on the local conditions.

DAILY WATER REQUIREMENTS

The following requirements are based on the average daily needs over a period of one year, except for the garden. Under extreme summer conditions, the requirements may be greater than those listed, while in the winter they will likely be much less.

1.	Person	25 gallons	(This should be increased to 50 gallons if inside plumbing is complete)
2.	Cattle	15 gallons/head	(For dairy cattle add 2 gallons for each gallon of milk produced.)
3.	Horses and mules	12-15 gallons/head	
4.	Sheep and goats	2 gallons/head	
5.	Mature hogs	3 gallons/head	
6.	Chickens	3 gallons/100	
7.	Turkeys	6 gallons/100	
8.	Garden	200 gallons/1000 sq. ft.	

The estimate for garden is based on the irrigation requirement of 3 feet depth of water for the year over a 4-month period, or an average of 9 inches of water per month.

The above estimates take care of only a minimum amount of loss due to evaporation and seepage, and for purposes of estimating these water requirements should be considered as "net." The estimates should be increased to provide for possible excessive evaporation or seepage.

In estimating the water requirements for the garden, seepage is an important factor to consider, influenced by nature of soil, length of small ditch runs, and size of supply head. The evaporation from the water surfaces of tanks and troughs will result in considerable loss of water, especially in the dry hot months when this loss may amount to as much as 1 inch depth per day. The evaporation from open tanks is much greater than from covered tanks. Wastage of water due to the use of spigots, or to leaky spigots and connections, should be taken into account. Considerable waste can be expected at all watering places, such as tubs, pans, and troughs. The overall water requirements, all possible losses taken into consideration, will ordinarily exceed the net requirements. The requirements for the most severe period of days or months will determine the demand capacity of well, pump, and storage facilities.

WELLS

Wells will probably be the most common type of farmstead water developments. The depth and yield of wells will vary over the Region. In all wells, however, first consideration should be directed towards obtaining a safe water supply, that is, one free from pollution, and so designed as to be easily maintained pollution-free. Most of the States have well-established sanitary codes. These should be fully observed in planning farmstead water supplies. Where the State Codes have not been fully developed (as in Arizona), the U. S. Public Health Codes should be followed. Second consideration should be to obtain the water in the most economical manner, not solely from first cost but for a long-time average, that is, so set up that maintenance will be held to a minimum. Often the use of too small casing or poor casing, though saving some first cost, so reduces the life of the development that the overall economy is poor.

A few very important factors should be kept in mind while selecting sites for well and elevated storage tank locations. These are:

1. A well should always be located above or out of the drainage line and protected from pollution from barns, chicken houses, hog pens, stomp lots, and outdoor toilets.
2. A well should not be located in a natural drainageway unless the only possible water is found there. When such a location is made, provision should be made to prevent damage to the well by run-off water.
3. When possible, the well and storage tank should be located on the higher portion of the farmstead and near the house.
4. The elevated storage tank should be located so as to eliminate necessity for an excessively high tower.

Well Casing

Generally where depths greater than 100 feet are known to be necessary, or where it is likely that rock will be encountered, a drilled well should be planned with a minimum diameter of 5 inches. In drilling deep wells, however, it is often impossible to drive one size or casing the entire depth. Under these conditions it is well to use larger casing for the upper portion, insert the smaller size inside, and drill to the desired depth. The larger pipe can then be pulled and used over and over again. The logic of this method is evident. If a well is started with the minimum sized casing and it is impossible to drive the casing to the desired depth, the only thing left to do is to start all over again; if larger casing is started, smaller casing can be inserted inside when further driving is impossible and drilling can be continued. Conditions vary widely: in some cases a single size casing has been driven to deep depths and in others only to very shallow. The best key will probably be the experience of drillers in each locality. The experience of the U. S. Indian Service has been such that they recommend the following starting size of pipe for the following estimated depths:

Size of Casing	Total Depth of Well
12 in.	600 ft.
10 "	400 "
7-5/8 "	300 "
5 "	100 "

By employing these sizes it is usually possible to end up with a 5" pipe, the smallest size for ease of bailing if the hole fills with sand.

The hole should be straight and extend well into or through the water bearing aquifer. The depth will depend on the location. Average depths in proven areas may be determined by talking with a local driller or inquiring as to depth of wells on adjoining farms. In unproven and questionable areas, the services of the S.C.S. geologist will be made available wherever possible to determine the feasibility, best location, and approximate depths.

All wells should be cased their entire depth. The casing of a well is desirable not only to prevent material from falling into the well, or to avoid the loss of the hole, but also to prevent water of undesirable quality from entering the well and to prevent the escape of good water from the well. For this purpose standard pipe, or better, is recommended. Wells drilled by the S.C.S. under the Water Facilities Program have consistently used standard pipe, with the alternate usage of either screw joint or butt-welded casing, depending on whichever is the cheaper. Butt-welded casing offers less resistance to driving due to lack of couplings. The U. S. Indian Service, on the other hand, does not like standard pipe but uses well casing, all screw joint. Their experience with standard pipe is that it rolls at the couplings whenever the driving is hard. The type of casing selected will depend upon the experience and judgment of the individual, taking into consideration the anticipated depth and ease of expected driving (type of material drilled through), and other pertinent factors.

No deteriorated casing should be used. Oil well casing or extra heavy pipe that is used but in good condition will be acceptable, and in some respects such pipe may be superior to standard pipe.

In several States (Utah and parts of New Mexico) in the Region, the State Engineer has authority to inspect and approve the casing in any well. Since similar laws may be passed in other States, it is well to check with the State Engineer before any well project is started. Good casing is always good economy since the casing constitutes usually about half of the cost of a well and replacement of the casing is necessarily an expensive job.

Types of Wells

There are several general types of wells which are used in different parts of the country, depending on underground formations, depth of water bearing sands and gravels, and the requirements or demand. The types likely to be used in farmstead water development are: (1) Dug or bored; (2) driven; and (3) drilled.

Whichever method is used it is essential that a log be kept of every well, showing the various strata and their depth and thickness. This information proves valuable when future wells are planned.

Driven or drilled wells are preferable to dug wells whenever formations permit their use, because it is easier to construct and maintain such wells safe from contamination. Every well must be located so that it will be reasonably accessible for cleaning, repairs, tests, and inspection if necessary. No well should be closer than 10 feet to any building foundation or closer than 50 feet to any sewer, drainage line, septic tank, cesspool, or toilet. Location of the well near closely confined barnyards or accumulations of manure should also be avoided.

Where only a small quantity of water is needed, and a reasonably safe water can be secured within 20 to 30 feet of the surface, dug, driven, or bored wells should prove satisfactory. For depths up to 100 feet the small diameter (1-1/2" to 3") open-end driven wells have been used, depending on the ground formation. If greater depths are necessary or rock is likely to be encountered, at least a 5" drilled well should be planned.

It is essential that all wells, dug, driven, or drilled, should be covered or have a pump base placed over them. Covers should be made watertight, preferably constructed of concrete with sufficient slope to drain water away from the pump. (See Fig. 5.)

Dug and Bored Wells

Dug and bored wells are generally shallow wells which tap a water-bearing formation near the ground surface.

The essential requirements to obtain a safe water supply from dug wells are as follows:

1. Proper location away from any source of contamination.
2. Watertight casing or curbing at least 10 feet below the natural ground surface and to greater depth where necessary to reach firm and compact impervious stratum, and 8 to 12" above the ground surface to provide good surface drainage away from the well.
3. The well cover or pump slab must be of watertight material, preferably concrete, and sealed to the top of the curbing in a watertight manner.
4. The opening for the pump cylinder shall be large enough to easily admit the cylinder but shall be designed for watertight closure after the cylinder is installed.
5. Where manholes are provided, they must have overlapping covers which can be maintained watertight and dustproof.

Driven Wells

Shallow tubular wells, called driven wells, are sunk in various ways, depending on the size and depth of the well and the nature of the material or strata encountered. In the construction of driven wells there are two principal methods of sinking such wells: the "closed end well" and the "open end well."

The closed end construction method consists of driving the well tube into the ground by a wooden maul or block until it penetrates the water bearing stratum. (The tube is a wrought iron or steel pipe from 1 to 4 inches in diameter, closed and pointed at one end and perforated for some distance from the end.) The upper end of the tube is connected to a pump, and the well is complete except for developing. This type of well is adapted for use in soft ground and for depths not to exceed 25 or 30 feet.

The open end construction is used in harder ground, for larger sizes and for greater depths than the closed end method. The well is sunk by removing the material from the interior, usually by means of a water jet, and at the same time driving the tube. If the ground is very hard or the well deep, a steel cutting shoe expedites the sinking of the tube.

With this type of well the lower portion of the casing may be perforated where the water bearing material is coarse. If sand is encountered, the perforations may be covered from the inside with brass gauze or the tube may be sunk, a strainer of suitable length inserted, the tube carefully withdrawn nearly to the top of the strainer, and a seal made just above where the strainer joins the lower part of the well casing. This is generally done with a lead packer.

The size of the strainer should be determined by an analysis of the grade of sand encountered in the water bearing stratum. It is best to locate the strainer so that it will be entirely under water at all times, and to assure this it should be kept below the limit of the suction.

Drilled Wells

Where depths in excess of 75 to 100 feet are necessary, the small driven well ceases to be an economical method of construction and drilled wells should be considered. A drilled well should meet the following requirements:

1. It should be of permanent watertight construction from above the permanent grade at the well to a continuous impervious formation, or to a "safe depth" below the probable present or future maximum drawdown.
2. The opening surrounding the well casing should be sealed with impervious material to prevent any movement of water through it.
3. The upper casing pipe terminal must be sealed against influent, that is, entrance of water of any kind.

Perforations. Perforations are of two types: (1) Those made by a perforating machine after the well is drilled and while the casing is in the hole, and (2) machine perforations which are cut in the factory.

The size and number of perforations are both important. If drilling samples are taken as the well is drilled, a satisfactory size of perforation may be selected. In the alluvial formations that contain most of the water in this Region, it is commonly considered that the size of perforations should be chosen so that about 60 percent of the grains will pass through the openings and about 40 percent will be retained outside the casing. Then as the finer material is pumped out, the larger grains settle around the casing, forming an envelope area with greater porosity and larger passages for transmission of water to the well.

Pumping tests will determine whether or not there are sufficient perforations. If the test indicates lack of perforations, additional perforations should be added.

Wherever a strainer is placed, it must be good quality red brass, or its equivalent, and of sufficient length to admit a reasonable quantity of water under normal pumping conditions.

Well Drilling

In the drilling of a well it is of first importance to acquire the services of an experienced well driller who can show that he has the necessary facilities, experience, and ability to perform the drilling in a satisfactory manner, that is, to drill a well that will be straight and vertical.

The type of drilling most suited to a particular region is best determined by local conditions and from local drillers. The general type of drilling done in the west is the standard method. While dug wells, bored wells, and driven wells may have some place in development of farmstead water where the water table is at shallow depths, by far the great proportion of the wells will probably be classified as drilled wells. Under drilled wells are wells drilled by the standard method, the California or stovepipe method, the sand pump or orange-peel method, the hydraulic-rotary method, the jetting method and the hollow-rod or self-cleaning method. For wells in the variety of materials likely to be encountered in S.C.S. Region 8, the standard method probably has the most general application. Where there is any uncertainty both as to required depth, type of materials that will be encountered, and thickness and type of water bearing material, the standard rig in the hands of an experienced well driller will give as good results as any if not the best.

Sample drilling Specifications, Invitations to Bid, and typical Contracts may be obtained by addressing a request to the Regional Conservator of the Soil Conservation Service.

Costs of well drilling vary widely, depending mainly on the type of material encountered. In unprospected localities of more or less unknown conditions, the costs may be higher than would be the case if the area has been thoroughly proven. Another feature that may affect the costs is the distance a driller will have to move his rig. If there are no drillers in the near vicinity and the proposed well is relatively shallow, then the unit costs may be excessively high to cover cost of moving rig in and out of the site. If, on the other hand, the driller and his rig are nearby and there is lots of drilling to do, then the costs may be lower than average.

Another feature that may influence costs is the way the money is set up. If the area is not prospected, the actual required depth exceeds the geologist's estimate, and there is not sufficient money set up to drill to the water bearing material, the time the driller will have to wait until additional funds are secured may adversely influence subsequent bids in the vicinity. Actual cost of drilling in average conditions is relatively reasonable.

The following summary of costs per foot of drilling has been worked out by Rohwer: [1]

Diameter: (Inches)	Arizona Drilling	Arizona Casing	Colorado Drilling	Colorado Casing	New Mexico Drilling	New Mexico Casing	Utah Drilling	Utah Casing
4							$ 1.00	
6	$ .75 to 1.00		$1.00				1.25 to 2.00	
8	1.25 to 1.50						2.00 to 3.00	
10	1.50 to 1.75				$ 2.50		3.00 to 4.00	

Average drilling costs in New Mexico for the first 100 feet of drilling are about as follows:

4" and 6"	$1.50 per ft.
8"	2.00 " "
10"	2.50 " "

with a 50¢ per foot raise for each additional 100 feet of depth.

The U. S. Indian Service in the southwest owns drilling rigs which they move from location to location as required in the drilling program. The costs naturally vary widely, depending upon the material drilled in, freight rates on the materials used in the well, distance from the railroad to truck materials, and the distances to move the well rig between drilling operations. With these variations the Indian Service considers about $10 per foot of hole ample to cover the entire cost of the complete well and development, including drilling, casing, pump, windmill, developing, etc. This cost is for wells about 200 to 350 feet in depth and 6" to 10" in diameter. The cost decreases to about $8 per foot for wells up to 200 feet and increases to about $12 per foot for wells from 350 to 500 feet in depth.

1/ Rohwer, Carl: "Putting Down and Developing Wells for Irrigation." U. S. Department of Agriculture Circular No. 546. February 1940.

The cost of farmstead wells (drilling only) in S.C.S. Region 6 has varied between 50¢ and $1.00 per foot.

PUMPING EQUIPMENT

Where a windmill is to be used to pump water from a well, the quantity of water that can be pumped will depend on the yield of the well and the pumping equipment, that is, the size of the wheel and sails, wind velocity, size of cylinder, and the elevation the water must be lifted. The selection of the cylinder and windmill should be consistent with the water requirement.

Cylinder

The cylinder size should be determined by the water requirement, depth of well, and size of wheel. It is recommended that the unit (wheel and cylinder) be designed to produce three times the daily water requirement during a 24-hour period, based on a continuous wind with an average velocity of the vicinity, or about 8 miles per hour in S.C.S. Region 8. Therefore, if the daily water requirement of a farm unit is 1000 gallons per day, determine from Table 1 the wheel and cylinder size necessary to provide 3000 gallons in a 24-hour period for the appropriate depth of the well. Do not use too large a cylinder. A windmill with a small cylinder running, pumps more water than a large one standing still a great part of the time.

It is recommended that a cylinder be used, the leathers of which can be replaced by pulling the sucker rods only. The top cap of this cylinder is the next pipe size larger than the cylinder size. This allows the valves to be withdrawn from the cylinder for repairs or leather replacements without pulling the pipe.

One of the controlling factors in setting the cylinder and determining the length of stroke applicable to the well is the type of water-bearing material. If the water-bearing material is coarse and there is little or no danger of fine material entering the well, then the cylinder may be set on the long stroke and placed near the bottom of the hole. But if the water-bearing material is fine and there is danger that some of this material may enter the hole, the stroke should be short and the cylinder set as high as possible to prevent the sand clogging the cylinder.

In many of the wells of the Southwest Region, the silt or fine sand that enters the hole through the perforations causes considerable trouble. Wearing action of the sandy material requires replacement of leather washers about twice a year and in some cases occasional bailing of the well. Therefore the cylinder setting should receive careful consideration to eliminate frequent trouble. The ball type valve under these conditions gives better service than the spool type, and four leathers on the plunger give best results.

The sucker rod should be set so that the valves work in the upper part of the barrel first and then lower as the barrel wears larger. This keeps that part of the barrel above the valves always the same size or larger than the portion of the barrel in which the leathers are working.

Windmills

There are numerous manufacturers of windmills, each claiming different performance qualities for his product. In some instances these performance charts differ widely and in other cases they do not differ a great deal. One windmill (Aermotor) has a design such that the length of the stroke is increased in proportion to the size of the wheel, and since the larger wheels make fewer strokes per minute, the pumping capacity of all mills from 8 to 16 feet, with the same size cylinder, is the same. On the other hand, other mills (Dempster and Sampson) increase pumping capacity by installing larger mills on the same size of cylinders.

Table I has been interpolated from various manufacturers' circulars. Whenever variation was found, the lowest value was used. It is meant to serve only as a basis for estimating. When all conditions are known, such as quantity of water available, quantity of water required, depth to water, drawdown and available wind, a mill to meet the exact conditions can be obtained from one of the various manufacturers.

Table II also has been interpolated from various manufacturers' tables and the same conditions prevail. In all probability, windmills are designed for the Middle West where there is more wind available than in S.C.S. Region 8; consequently an attempt has been made to show performance tables in terms of lower wind velocities.

The table of wind velocities (in part) as presented by the Sampson Company, is as follows:

Average Hourly Velocity of the Wind
at the Following Stations of the U. S. Weather Bureau

Given in Miles per Hour

Amarillo	Texas	11.0	North Platte,	Nebraska	10.3
Cheyenne,	Wyoming	10.5	Prescott,	Arizona	6.5
Denver,	Colorado	6.7	Salt Lake City,	Utah	5.3
Dodge City,	Kansas	11.8	Santa Fe,	New Mexico	7.0
El Paso,	Texas	6.3	Yuma,	Arizona	6.0
Leavenworth,	Kansas	7.1			

Table I

Pumping Capacities of Windmills
for Various Elevations and Various Wind Velocities

Elevation in the following tables means the vertical distance between the water level in the well when being pumped and the highest point to which the water is being lifted, such as the top of the storage tank. G.P.D. means gallons per day.

Size of Wheel	Stroke	8 Mile Wind Cyl.	8 Mile Wind G.P.D.	10 Mile Wind Cyl.	10 Mile Wind G.P.D.	15 Mile Wind Cyl.	15 Mile Wind G.P.D.	8 Mile Wind Cyl.	8 Mile Wind G.P.D.	10 Mile Wind Cyl.	10 Mile Wind G.P.D.	15 Mile Wind Cyl.	15 Mile Wind G.P.D.
Ft.	In.	In.		In.		In.		In.		In.		In.	
		15 FT. ELEVATION						25 FT. ELEVATION					
6	3-5/8	4	3120	4	4400	4	7100	4	3120	4	4400	4	7100
6	6	4	5200	4	7000	4	11800	3-1/2	3960	3-1/2	5400	3-1/2	9000
		35 FT. ELEVATION						50 FT. ELEVATION					
6	3-5/8	3-1/2	2400	3-1/2	3260	3-1/2	5440	2-3/4	1480	2-3/4	2010	2-3/4	3350
6	6	3	2910	3	3960	3	6600	2-1/4	1630	2-1/4	2230	2-1/4	3710
8	6	4	5170	4	7050	4	11800	3-1/2	3960	3-1/2	5400	3-1/2	9000
8	8	3-1/2	5250	3-1/2	7200	3-1/2	12000	3	3890	3	5300	3	8850
10	7-1/2							4-1/4	6000	4-1/4	8120	4-1/4	13500
10	10							4	7000	4	9550	4	15900
		75 FT. ELEVATION						100 FT. ELEVATION					
6	3-5/8	2	780	2	1060	2	1775						
6	6	1-3/4	990	1-3/4	1350	1-3/4	2250						
8	6	2-3/4	2450	2-3/4	3320	2-3/4	5550	2	1720	2	2350	2	3910
8	8	2-1/2	2700	2-1/2	3670	2-1/2	6100	2-1/4	1790	2-1/4	2440	2-1/4	4070
10	7-1/2	3-1/2	4020	3-1/2	5480	3-1/2	9130	3	2950	3	4020	3	6700
10	10	3	3940	3	5350	3	8930	2-3/4	3300	2-3/4	4520	2-3/4	7520
12	9	4	5150	4	6900	4	11500	3-1/4	3360	3-1/4	4600	3-1/4	7650
12	12	3-3/4	5960	3-3/4	8130	3-3/4	13500	3-1/4	4470	3-1/4	6100	3-1/4	10150

Table I (Cont'd)

Size of Wheel	Stroke	125 FT. ELEVATION						150 FT. ELEVATION					
		8 Mile Wind		10 Mile Wind		15 Mile Wind		8 Mile Wind		10 Mile Wind		15 Mile Wind	
		Cyl.	G.P.D.	Cyl.	G.P.D.	Cyl.	G.P.D.	Cyl.	G.P.D.	Cyl.	G.P.D.	Cyl.	G.P.D.
Ft.	In.	In.		In.		In.		In.		In.		In.	
8	6	2	1290	2	1760	2	2940	2	1290	2	1760	2	2940
8	8	1-3/4	1315	1-3/4	1800	1-3/4	3000	1-3/4	1315	1-3/4	1800	1-3/4	3000
10	7-1/2	2-3/4	2480	2-3/4	3380	2-3/4	5630	2-1/2	2040	2-1/2	2800	2-1/2	4650
10	10	2-1/2	2740	2-1/2	3750	2-1/2	6220	2-1/4	2200	2-1/4	3000	2-1/4	5040
12	9	3	2860	3	3900	3	6500	2-3/4	2410	2-3/4	3280	2-3/4	5450
12	12	2-3/4	3210	2-3/4	4370	2-3/4	7300	2-1/2	2650	2-1/2	3620	2-1/2	6040
14	10-1/2	3-3/4	4480	3-3/4	6130	3-3/4	10200	3-3/4	4470	3-3/4	6070	3-3/4	10200
14	14	3-3/4	5950	3-3/4	8150	3-3/4	13600	3-1/4	4470	3-1/4	6070	3-3/4	10200
		200 FT. ELEVATION						250 FT. ELEVATION					
10	7-1/2	2-1/4	1660	2-1/4	2280	2-1/4	3780	2	1310	2	1790	2	3000
10	10	2	1750	2	2380	2	3980	1-7/8	1540	1-7/8	2100	1-7/8	3500
12	9	2-1/2	2000	2-1/2	2700	2-1/2	4500	2-1/4	1600	2-1/4	2200	2-1/4	3660
12	12	2-1/4	2150	2-1/4	2920	2-1/4	4870	2	1690	2	2300	2	3860
14	10-1/2	3-1/4	3360	3-1/4	4580	3-1/4	7650	2-3/4	2400	2-3/4	3230	2-3/4	5480
14	14	2-3/4	3200	2-3/4	4360	2-3/4	7300	2-3/4	3200	2-3/4	4380	2-3/4	7300
		300 FT. ELEVATION						350 FT. ELEVATION					
10	7-1/2	1-3/4	1000	1-3/4	1370	1-3/4	2280						
10	10	1-3/4	1340	1-3/4	1810	1-3/4	3040						
12	9	1-7/8	1110	1-7/8	1510	1-7/8	2530						
12	12	1-3/4	1300	1-3/4	1770	1-3/4	2950						
14	10-1/2	2-1/4	1610	2-1/4	2200	2-1/4	3650	2-1/4	1610	2-1/4	2200	2-1/4	3650
14	14	2-1/4	2150	2-1/4	2920	2-1/4	4880	2-1/4	2150	2-1/4	2920	2-1/4	4880

Table I (Cont'd)

Size of Wheel	Stroke	400 FT. ELEVATION: 8 Mile Wind Cyl.	400 FT. 8 Mile Wind G.P.D.	400 FT. 10 Mile Wind Cyl.	400 FT. 10 Mile Wind G.P.D.	400 FT. 15 Mile Wind Cyl.	400 FT. 15 Mile Wind G.P.D.	450 FT. ELEVATION: 8 Mile Wind Cyl.	450 FT. 8 Mile Wind G.P.D.	450 FT. 10 Mile Wind Cyl.	450 FT. 10 Mile Wind G.P.D.	450 FT. 15 Mile Wind Cyl.	450 FT. 15 Mile Wind G.P.D.
Ft.	In.	In.		In.		In.		In.		In.		In.	
14	10-1/2	2-1/4	1610	2-1/4	2200	2-1/4	3650						
14	14	1-7/8	1490	1-7/8	2030	1-7/8	3380						
16	12	2-1/2	2020	2-1/2	2750	2-1/2	4590	2-1/4	1640	2-1/4	2240	2-1/4	3600
16	16	2-1/2	2700	2-1/2	3680	2-1/2	6130	2-1/4	2180	2-1/4	3000	2-1/4	4950
18	12	3-1/4	3200	3-1/4	4350	3-1/4	7300	3-1/4	3200	3-1/4	4350	3-1/4	7300
18	16	3-1/4	4000	3-1/4	5430	3-1/4	9050	3-1/4	4000	3-1/4	5430	3-1/4	9050

500 FT. ELEVATION

Size of Wheel (Ft.)	Stroke (In.)	8 Mile Wind Cyl. (In.)	8 Mile Wind G.P.D.	10 Mile Wind Cyl. (In.)	10 Mile Wind G.P.D.	15 Mile Wind Cyl. (In.)	15 Mile Wind G.P.D.
16	12	2	1290	2	1760	2	2980
16	16	2	1720	2	2340	2	3910
18	12	3-1/4	3200	3-1/4	4350	3-1/4	7300
18	16	3-1/4	4000	3-1/4	5430	3-1/4	9050

TABLE II.

Elevation in Feet to Which Water Can Be Raised with Various Sized Windmills and Cylinders

Size of Cylinder (Inches)	Size of Windmill Wheel					
	6 ft.	8 ft.	10 ft.	12 ft.	14 ft.	16 ft.
1-3/4	80	185	280	420	600	1000
1-7/8	77	175	260	390	560	920
2	67	150	215	320	460	750
2-1/4	50	119	189	250	360	590
2-1/2	46	98	158	210	300	490
2-3/4	38	82	125	180	260	425
3	32	67	111	155	220	360
3-1/4	26	58	92	130	185	305
3-1/2	22	50	83	115	160	265
3-3/4	19	45	72	98	143	230
4	17	37	63	86	125	200
4-1/2		30	47	68	98	160
5		24	38	55	80	130
6		17	25	38	55	85
7			19	28	41	65
8			14	22	31	50

If your nearest Weather Bureau office cannot tell you the prevailing wind velocity in your locality, the following will help you to make a reasonably accurate estimate.

Winds up to 8 miles per hour rustle leaves and can be felt on the face.

Winds from 8 to 12 miles per hour will extend a light flag and keep small twigs in motion.

Winds from 13 to 18 miles per hour sway small branches and move dust and litter.

Winds from 19 to 24 miles per hour sway small trees and blow up crested waves on ponds and lakes.

Most of the windmill-manufacturing concerns are located in the Middle West and East where windmill installations are more common. Consequently most windmills start operation at about 7 miles per hour and reach their best efficiency at about 15 to 18 miles per hour for the smaller wheels, and 18 to 20 miles per hour for the larger wheels. Since there is less wind in the mountain regions of Region 8, it is suggested that a factor of safety of about 5 should be inserted either in the size of mill and cylinder or in the amount of time it is expected that the mill will pump, if a manufacturer's rating is used. The following specifications for the mill and tower are recommended.

Windmill

The wheel sails shall be manufactured from hard galvanized prime sheets, and shall be firmly fastened to the spider or hub to hold their shape permanently and in such a manner that they will not easily loosen. The hub or spider to be firmly keyed to the shaft and locked in place. The arms to be of high-grade structural steel and substantially fabricated. Wooden wheels are not acceptable without special justification.

Motor or Mill Head

The motor shall be of the self-oiling type for positive delivery of oil to all bearings and with an oil capacity sufficient to last at least 9 months without replenishing. The crankcase to be of cast iron and the hood to be made of cast iron or heavy galvanized steel accurately fitted so that the entire assembly shall be absolutely dust and weatherproof. All gears and pinions shall be machine-cut or molded from suitable iron or steel. Wheel and gear shafts shall be fitted with suitable high-grade roller, ball, removable plain babbitt or bronze bearings, or equal. The mill shall be fitted with a positive brake and a sensitive automatic adjustable governor. The turntable shall be fitted with a high-grade ball thrust bearing; having hardened ground steel races. Provision should be made for

adjusting the length of the stroke and the swivel shall be self-oiling. All exposed cast iron parts shall be painted with a durable weather-proof paint. All steel parts shall be galvanized or cadmium-plated after fabrication, including bolts, nuts, and lock washers.

Windmill Tower

Specifications for both steel and wooden towers are included, and preference will depend on the type of installation required. Wooden towers do not attract lightning as steel towers do; they withstand wind in a more satisfactory manner than do the commonly used steel towers, and where the farmer or other person for whom development is made is a skilled carpenter, wooden towers are adaptable to erection by the owner of the facility at a saving in cost. On the other hand, the experience of the U. S. Indian Service and S.C.S. in this Region has been that wood towers and tanks, due to alternate wetting and drying, have a shorter life and are subject to more repairs. In general, steel towers are preferred for windmills in this Region.

The tower should be of sufficient height that the wheel will be entirely above all surrounding buildings and trees. A 30- to 35-foot tower is ordinarily recommended but in a location with high surrounding buildings or trees a 40-foot tower may be required.

Specifications for wooden towers have been taken from the Handbook prepared by S.C.S. Region 6. (See Figures 1 and 2.)

A steel windmill tower must meet the following specifications: The tower shall be the 4-post type, ruggedly constructed with angle irons for corner posts and angle irons for girts, and of sufficiently sturdy design to withstand a wind pressure of 25 pounds per square foot of projected area of tower and windmill. The braces shall be steel rods or bars threaded on at least one end for adjustment or tightening. The platform shall be strongly made from lumber or steel and of sufficient size to accommodate a man working on the mill, and of sufficient strength to support equipment used in pulling the pump. All tower bolts and nuts shall be equipped with lock washers. The design and fabrication of the tower shall be such as will reduce to a minimum shearing strains on bolts and other members of the structure and to assure rigidity and prevent buckling, bending, or twisting in erection and operation. The tower shall be provided with an adequate ladder firmly held in place for safe climbing. All metal tower materials, including ladder and metal platform, must be of high-grade steel and shall be either galvanized or cadmium-plated after fabrication. All bolts, nuts, and washers, including those required for field erection, shall be of high-grade steel and shall be galvanized, sherardized, or given other similar treatment to prevent rust or corrosion. The tower is to be provided with anchor posts suitable for casting in concrete, and it is recommended that the corner posts be cast in concrete footings.

The minimum sizes of corner posts recommended are as follows:

Size of Mill	Size of Angle for Corner
6 or 8 ft.	2-1/4 x 2-1/4 x 1/8
10 "	2-1/2 x 2-1/2 x 1/8
12 "	3 x 3 x 1/8
14 "	3 x 3 x 3/16
16 "	3 x 3 x 1/4
18 "	3-1/2 x 3-1/2 x 1/4

Pump Pole Guides

The tower shall be equipped with sufficient pump pole guides to keep the pump pole in proper alignment without binding or interfering with the action of the rod.

Sucker Rods

Steel sucker rods are recommended all the way up except one short wood rod at the surface to absorb the spring. Wooden sucker rods are not recommended as they have been known to introduce bacteria into a water supply, and because they do become waterlogged and add considerable extra weight for the windmill or engine to lift. Hollow steel rods are recommended since there is a certain amount of buoyancy and a larger moment of inertia or greater resistance to whipping. When solid steel rods are used, there is a certain amount of whipping unless large rods are used and these large rods add extra weight to be lifted by the mill or motor.

The sizes of sucker rods recommended are as follows:

Size of Cylinder	Hollow Steel Rods	Wooden Rods
1-3/4 to 1-7/8"	5/8"	1-1/8"
2 to 3-1/4"	7/8"	1-3/8"
3-1/2 to 4"	1"	1-7/8"

Depth of well will also influence size of rods.

Galvanized rods, galvanized couplings, and copper or cadmium-plated rivets are recommended in order to protect against possible action of minerals in the water.

Hand Pumps

Hand pumps for relatively shallow wells are available in many sizes and types from the little pitcher pump to those suitable for windmill and pump-jack connections. Hand pumps are suitable for situations where only a limited amount of water is required and are not recommended for household use.

Tubing and Fittings

All riser tubing should be "galvanized, plugged, and reamed" and of standard weight. The size of the tubing should be the next standard size larger than the cylinder, in order to allow the valves to be withdrawn for repair or replacement of leathers without pulling the pipe.

The tubing must be suspended by means of some type of clamp. A clamp may be fabricated from 1/2" or 3/8" steel strap. The most satisfactory method of suspension is a cast iron pipe holder. Such a holder is equipped with set screws to steady the pipe, and covers the entire top of the casing. A coupling, tee, or some other fitting should be placed immediately above the clamp and rest on it to carry the weight of the load. An asphalt seal is recommended between the pipe holder and the tubing, and the pipe holder and the casing, in order to assure tight joints. (For details see Figs. 3, 4, and 5.)

It is recommended that a tee with a 1/2" or 3/4" opening be used above the clamp and a hose bib or faucet be attached here. This will provide a place to get drinking water and also a means of draining the riser pipe during cold weather.

An automatic drain for prevention of freezing in cold weather has been used by the U. S. Indian Service. It consists of a small hole, 1/8 to 3/16 inches in diameter, in the tubing about 3 feet below the ground surface. This hole is left open and drains the tube above whenever the mill is not running. Where constant attention or some other means of frost protection is not maintained during cold weather, this method of frost protection is recommended.

In all locations where there are low freezing temperatures, it is recommended that the riser pipe be insulated from the ground to the delivery to the storage tank. This may be done by building a box around the pipe and filling it with sawdust, cottonseed hulls, or other suitable material. The supply pipe, if located below the ground surface, should be buried 9" below the frost line, with a minimum of 24" recommended.

Pump Jacks and Motors

The need for a pump jack and motor for supplemental pumping will best be determined from surrounding installations, storage capacity of the development, and the daily water requirements. The experience of the Indian Service in their stock water developments has been that about 40 percent of their wells need pumping for a period of 8 to 9 months each year; consequently, in most locations where windmill power is relied upon, a pump jack should be at least investigated.

Pump jacks should have all gears enclosed. This design not only insures perfect and complete lubrication but also protects the moving parts from dust and dirt. Furthermore, it is a guarantee of safety for the operators compelled to work around them. The stroke of the pump jack should be the same as the stroke of the windmill. This allows for use of the most economical cylinder, pump jack, and motor. Because of its principle of operation, the pump jack must be installed directly over the well.

The capacity of pumping equipment for any installation should be sufficient to pump an amount of water in 8 hours equal to the maximum daily consumption. The capacity in gallons per hour, therefore, should be not less than 1/8 of the maximum daily consumption.

The requirements of each individual installation should be definitely stated in the advertisement for pumping equipment, including maximum lift, total pumping head, yield of well, requirements of pump, availability of electricity, etc., that each manufacturer will clearly understand what the pumping equipment must satisfy.

Where electric power is not available, gasoline engines should be used. In general, the one-cylinder hopper cooled type is recommended both from initial cost and length of service standpoint. The experience of the U. S. Indian Service in the high altitudes of S.C.S. Region 8 has been that the manufacturers' rating is light and for best service it is well to use the next larger size.

All power pumps should be set on a pump base elevated 8 to 12 inches above the floor slab of the well, and the casing of the well given sufficient height to provide the proper watertight seal when the pump is set at this elevation.

The motor-driven pump should be properly suited to the installation and designed to give long-life service with high efficiency and a minimum of maintenance. The pump and motor shall be balanced so that the unit will start quickly and operate with no excess vibration. The motor and pump shall be connected so that

there will be a minimum of slippage. All parts shall be accurately machined and similar parts of the pump interchangeable. All equipment shall be neatly finished and well painted.

The size of motor required may be estimated from Table III, which shows the required horsepower to pump water, based on an overall plant efficiency of 25 percent.

Storage Tank

The tank should have a minimum capacity equal to five times the daily water requirement to care for periods of no wind. If a pump jack and motor is installed for pumping during days of no wind, this capacity may be reduced to about 1-1/2 to 2 times the daily water requirement or the same reduction may be made where there is supplemental storage equivalent to 7 to 10 days' steck water.

Either wooden storage tanks of cypress or redwood or metal tanks may be used, depending on local conditions and costs. If the tank is likely to be alternately wet and dry, a metal tank is recommended. If there are minerals in the water that will cause corrosion of metal, that is, eat off the galvanizing, then a wooden tank is recommended. Generally metal tanks are recommended since they stand up better, require less maintenance, and are more permanent, and usually the extra cost, if any, may be well justified. However, small lightweight metal tanks are not recommended where the draw-off is light as the water will become warm in such tanks during the summer months. Tank dimensions may be determined from Tables IV, V, and VI, after water requirements are known. (See pages 22 and 23.)

In all installations tanks should be covered. The cover for wooden tanks, illustrated in Figure 9, should be used only when the farmer can build it himself; otherwise metal covers are recommended.

Where wooden tanks are used, the bottom of the tank should rest firmly on the joists of the tower. No weight of the tank should be supported by the rim which extends below the tank bottom.

If it is desired to treat wooden tanks, either inside or out, information may be obtained for this treatment by addressing a request to the Regional Conservator, Soil Conservation Service, Albuquerque, New Mexico. Likewise, if it is desired to disinfect new tanks or equipment, advice may be obtained by referring to Section 4 of the S.C.S. Engineering Handbook or by addressing a request to the Regional Conservator.

In cold climates the tank should have a double roof, and care should be taken to select a tank large enough. Capacity will be reduced during cold spells by the formation of ice around the sides, which may be from 12 to 18 inches thick.

TABLE III.

Horsepower Required To Pump Water
(25% Over-all efficiency)

Gallons per Min.	Gallons in 8 Hrs.	Lift in Feet														
		15	25	35	50	75	100	125	150	200	250	300	350	400	450	500
1	480	.015	.025	.035	.05	.075	.10	.125	.15	.20	.25	.30	.35	.40	.45	.50
2	960	.03	.05	.07	.10	.15	.20	.25	.30	.40	.50	.60	.70	.80	.90	1.00
3	1,440	.045	.075	.105	.15	.225	.30	.375	.45	.60	.75	.90	1.05	1.20	1.35	1.50
4	1,920	.06	.10	.140	.20	.30	.40	.50	.60	.80	1.00	1.20	1.40	1.60	1.80	2.00
5	2,400	.075	.125	.175	.25	.375	.50	.625	.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
6	2,880	.09	.15	.210	.30	.45	.60	.75	.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00
7	3,360	.105	.175	.245	.35	.525	.70	.875	1.05	1.40	1.75	2.10	2.45	2.80	3.15	3.50
8	3,840	.12	.20	.280	.40	.60	.80	1.00	1.20	1.60	2.00	2.40	2.80	3.20	3.60	4.00
9	4,320	.135	.225	.315	.45	.675	.90	1.125	1.35	1.80	2.25	2.70	3.15	3.60	4.05	4.50
10	4,800	.150	.25	.35	.50	.75	1.00	1.25	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
15	7,200	.225	.375	.525	.75	1.125	1.50	1.875	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50
20	9,600	.300	.50	.70	1.00	1.50	2.00	2.50	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
25	12,000	.375	.625	.875	1.25	1.875	2.50	3.125	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50

TABLE IV. Storage Tank Capacities

Outside Length Staves	Outside Diameter Bottom	Capacity	
Feet	Feet	Gals.	Bbls.
6	7	1516	48
6	8	2000	63
7	7	1785	56
7	8	2352	74
7	9	3000	95
7	10	3723	118
8	8	2705	86
8	10	4282	136

TABLE V. Storage Tank Capacities

Outside Length Staves	Outside Diameter Bottom	Capacity	
Feet	Feet	Gals.	Bbls.
2	4	150	5
2	5	221	7
2	6	324	10
2	7	446	14
2	8	588	19
2	10	931	30
2	12	1550	49
2	14	2000	64
2	16	2500	80
2½	6	421	13
2½	7	580	18
2½	8	764	24
2½	10	1210	38
2½	12	1758	55
2½	14	2226	71
2½	16	2835	90

These tables were taken from Axtell Catalog and were computed for wood tanks.

Table VI

Steel Storage Tank Capacities (Gallons)

Depth: Ft.	DIAMETER (In Feet) 4	5	6	7	8	9	10	11	12
4	322	517	758	945	1410	1810	2230	2710	3125
5	405	652	945	1305	1785	2260	2790	3370	4040
6	487	780	1140	1565	2140	2710	3350	4060	4830
7	570	908	1330	1915	2510	3150	3920	4770	5650
7½	615	945	1425	2060	2680	3400	4190	5070	6050
8	652	1040	1590	2190	2860	3860	4475	5410	6460
10	820	1305	2020	2740	3580	4525	5600	6750	8060
12								8330	9680

The above table was taken from the Dempster Catalog.

Overhead storage tanks are seldom protected against freezing due to the large volume of water involved. Severe ice formation will not form unless very low temperatures extend over a considerable period of time and not then if large amounts of water are being used. Tanks which are relatively small and which are mounted on towers of ample strength can be protected by enclosing them in timber envelopes, filling the space thus provided with sawdust, shavings, or other nonconducting materials.

All riser pipes and hydrants should be well insulated irrespective of whether the tank is protected or not. Commercially prepared asbestos wrapping material is available for this purpose and is recommended.

Storage Tank Tower

Specifications for both wood and steel towers are included, and generally steel towers are recommended for much the same reason that steel towers are recommended for windmills. That discussion (see page16) is applicable to storage towers. The tower should be strong enough to hold the storage tank and water for the maximum anticipated installation. This policy is adopted in order that future storage requirements may not be limited by an inadequate tower.

In many instances where timber is available it has been found more economical to construct the towers of wood. Where wood construction is used, all timber should be treated to assure longer life. The split ring joint construction is recommended on this type of tower as it is much stronger than any lap joint construction. (See Figure 6.)

Drawings of both steel and wood towers are taken from the S.C.S. Engineering Handbook, Section 4. (See Figures 6 and 7.)

Only one riser pipe is necessary for a tank as this pipe can serve as supply and discharge by having the tank float valve on the system. Care must be exercised in making the pipe connection through the bottom of the tank so that the expansion and contraction in this pipe will not cause leaks to develop. A flange connection having a packing sleeve should be used which will eliminate the need for a union in the riser line and provide for a very satisfactory and watertight joint. These flange couplings can be obtained from tank manufacturers.

With small installations, it appears practical to construct a small tank in the windmill tower and thus eliminate the storage tank tower. Such construction proves satisfactory only where small tanks are required, but with larger installations, unless the tower is built sufficiently substantial, vibration tends to develop leaks, even in metal tanks. For this reason where storage of more than 1,000 gallons is required, it is recommended that the elevated tanks be erected on an individual tower.

Tower heights should be a minimum of 10 feet. In all cases the top of the tower should be 6 feet higher than the highest anticipated outlet in the water line. Footings for the tower should be made of concrete and the columns set in the concrete or bolted to it. If the columns are bolted down, 1/2 x 3" straps and 3/4" bolts should be used.

The standpipe type of tank is suitable for situations where the elevation of site will provide ample pressure when tank is nearly empty. No tower is required in this type installation.

FOOTINGS FOR TANK TOWERS AND WINDMILLS

In general, foundation conditions will vary widely over the Region, and care should be taken to make certain that the footings are large enough to prevent settlement, since settlement of one corner may throw excessive stresses in the structure. On the other hand, footings that are too large add unnecessary expense to the development. In general, a soil-bearing pressure of about 1500 pounds per square foot should be allowed. This will care for minimum conditions of alluvium or loam. Where foundations are unusual, either extra good or extra poor, an engineer or other person competent to advise on foundations should be consulted.

In addition to the actual weight of the structure, tower and mill, or tank, tower and water that must be carried by the footings, there is the added weight caused by wind pressure. For this Region the pressure caused by a 60-mile per hour wind should be used, and a suggested formula is $P = 0.0033 V^2$ in which V = wind velocity in miles per hour and P = wind pressure in pounds per square foot.

In the following tables, these conditions, namely, 1500 pounds per square foot for soil bearing capacity and a 50-mile per hour wind, have been used in design work.

The minimum size footing recommended is one 18" square and 15" thick. This will care for storage tank towers up to 1000-gallon capacity and 10 feet in height for either steel or wood towers, and for windmills up to 8 feet in diameter on 40-foot towers.

The following table shows a few typical storage tank towers and the recommended minimum size of footings. In addition, all footings should extend 9" below the frost line. Those not shown may be interpolated or figured from the above data.

Height of Tower	Size of Tank	FOOTINGS		
		Width	Length	Thickness
Ft.	Gal.			
10	1000	1' 5"	1' 6"	1' 0"
20	3000	2' 2"	2' 2"	1' 6"
30	3000	2' 6"	2' 6"	2' 0"
40	5000	3' 0"	3' 0"	2' 6"
50	10000	4' 6"	4' 6"	4' 0"

Foundations for windmill towers that have sufficient weight to prevent overturning are usually strong enough to prevent settlement. The buried type of anchor is generally recommended since the earthfill above the concrete block adds weight and takes the place of concrete. This buried anchor consists of an angle iron, of the same size or larger than the corner posts of the tower, 5 feet long for mills up to 14 feet, and 6' 8" long for 16-foot mills, with double angle plates bolted to the bottom to bolt to the concrete anchor block. For 33-foot windmill towers for 6, 8, 10, 12, and 14-foot mills, and a 40-foot tower for the 16-foot mill, the following size concrete blocks are recommended for footings, 5 feet below the ground surface for mills up to 14 feet in diameter and 6' 8" below the ground surface for 16-foot mills.

Size of Mill	FOOTINGS		
	Width	Length	Thickness
Ft.			
6	1' 6"	1' 6"	1' 3"
8	1' 6"	1' 6"	1' 3"
10	1'10"	1'10"	1' 8"
12	2' 0"	2' 0"	1'10"
14	2' 6"	2' 6"	2' 0"
16	3' 4"	3' 4"	2' 0"

CONCRETE RESERVOIRS

Where it is possible to gain sufficient elevation on the surrounding terrain, the storage tank tower may be eliminated. The surface storage tank or underground reservoir should be constructed of concrete or other impervious material and properly covered so that the water supply will be protected and can be maintained free from the possibility of contamination.

The location should be checked against contamination by surface drainage. Every effort must be made to have all drainage diverted from the reservoir site and the immediate area should be fenced to keep out both humans and animals.

IMPOUNDING PONDS

Impounding ponds or small reservoirs may be resorted to for farmstead use if no other source of supply is economically obtainable. Open ponds, more than any other type of storage, are subject to contamination. Extreme care is urged in the selecting of the storage site and the watershed from which the water originates. Recommendations of U. S. Department of Agriculture Farmers Bulletin No. 1859 should be followed. Utmost care in treating domestic supplies thus stored must be practiced. This is further discussed under "Surface Supplies," page 29.

SPRING DEVELOPMENTS

The cost of spring developments and the quality and quantity of water they will yield after development vary widely. The reason for the variable cost of development is the difference in type of development required for different springs, the quantities of various materials needed, such as cement, rock, drain tile, gravel, sand, and water pipe, the availability of sand and gravel, and the distance to truck labor and materials to the development site.

Farmer's Bulletin No. 1859 gives a description of general types of developments and types of materials needed. This bulletin contains helpful suggestions and should be consulted. Since it is written in general terms, however, each spring development will require individual planning.

As an aid to estimating costs, some material and labor costs are listed to be applied to total quantities of the development.

Cement		$ 0.95	per	sack
Reinforcing steel		.045	"	pound
Drain tile:	4 in.	.12	"	foot
	6 "	.19	"	"
	8 "	.30	"	"
	10 "	.45	"	"
Galvanized pipe:	3/4 in.	.08	"	"
	1 "	.1124	"	"
	1-1/4 "	.152	"	"
	1-1/2 "	.182	"	"
	2 "	.245	"	"
	2-1/2 "	.387	"	"
	3 "	.506	"	"

In general, a 1:2:4 mix or equivalent is recommended for concrete work. This requires approximately 6 sacks of cement, 0.9 cu.yd. of gravel, and 0.42 cu. yd. of sand for each cubic yard of concrete. Concrete made from clean, sound, and well graded sand and gravel, with 5 to 6 sacks of cement per cubic yard, well mixed with clean water not to exceed 7.5 gallons per sack of cement, and carefully tamped in place, should have the quality and compressive strength requisite for its use in the footings or in other ordinary farm structures. For proper curing, all concrete should be kept moist by covering or by the application of water to exposed surfaces for a period of at least seven days after placing.

The following is a brief summary of and quotations from Farmers Bulletin No. 1859, and the planner is referred to that publication for more detailed discussion.

Springs are of all gradations between concentrated outflows emerging at a single point to the diffused emergence of water over large areas. Usually springs have a fairly steady flow.

To develop a spring it is necessary to clean out the opening, locate the waterbearing material, provide some means for collecting the water and protect the development from surface pollution and surface damage.

Springs are classified many ways; however, in terms of development, they are usually classified according to the manner in which the water is brought to the surface, as "depression" springs and "contact" or "hillside" springs.

Since improper development may render a spring either entirely useless or less useful than if developed properly, it is essential to determine the true characteristics of a spring before any development is attempted. The discharge of a spring is dependent on the head or the elevation at which it discharges, and care should be taken not to increase the head even to shorten supply lines or gain elevation for the tanks since it may not only decrease the yield but may also cause the spring to change its course and emerge at some other point.

The development of seeps is often a gamble and to install a development of extensive excavations, ditching and tiling is usually expensive although a worthwhile spring may often be developed from what appears to be only a wet or swampy spot.

Depression Springs

The development of depression springs is somewhat uncertain. It is usually advisable to make a series of borings in the vicinity to determine the water table profile and the extent and movement of groundwater.

A spring encasement box is usually used where the flow is primarily upward. After the spring is excavated, a cribbing 3 or 4 feet square with a tight-fitting cover and overflow pipe is installed. The cribbing should extend to good foundations and a few feet above the ground and may consist of masonry, concrete, or other material. If there appears to be some horizontal flow, the lower part of the cribbing should be porous to allow the water to enter the cribbing.

Contact Springs

Contact springs generally emerge on hillside, and the inflow is in a downward or horizontal direction. The discharge may be limited to one point or a small area, or it may extend a considerable distance across the slope. Improvement and maintenance of flow depends largely on horizontal excavation and increased discharge along the top of the impervious stratum. The development must intercept and collect the flow, and borings or excavation vertically through the impervious stratum may result in a partial or complete loss of the spring.

A V-shaped collecting wall, preferably of concrete, at least 6 inches thick, with the ends extending far enough back into the hillside to prevent outcropping water from going around them, extending 1 to 2 feet above ground level and deep enough to reach good foundations and prevent underseepage, is commonly used. A galvanized pipe of large size is inserted at the desired height near the apex of the collecting wall to convey the spring discharge to a watering trough or reservoir. A generous amount of gravel and rock should be filled in behind the spring box and collecting wall to allow unrestricted passage of water. The porous material is then covered with soil and vegetal cover is installed to protect the surface.

Where spring water emerges at several widely spaced points, coarse gravel and rock-filled ditches or, preferably, open-jointed tile embedded in gravel-filled ditches, can be used for collecting water from outlying points, and thus the expense of extending collecting walls long distances is eliminated.

All springs should be protected from surface run-off and be enclosed by fence to exclude livestock. Springs can be easily polluted and should be protected from surface pollution.

The spring in every case should be permitted to enter the encasement unrestricted and flow out through a pipe or opening of sufficient size to take the flow of the spring and preferably not less than 1" in diameter. The encasement and overflow pipe should be planned so that the hydrostatic head on the spring will be kept to a minimum.

SURFACE SUPPLIES

In some localities it is not possible to obtain a domestic water supply from wells or springs and in such cases supplies are derived from surface streams or the collection of rainwater, either from rock ledges or roofs. These sources should be used only as a last resort and before being used for drinking purposes should be chlorinated. Where necessary, additional treatment, involving sedimentation and filtration, should be provided.

The method of collecting water will vary widely. In some cases it may be necessary to collect intermittent flows in an impounding reservoir much the same as is done for stock water, allow it to settle, then filter and chlorinate it and store in a cistern for use.

This method of obtaining drinking water is not new. Many towns and cities collect and store water in impounding reservoirs. The type of water thus obtained depends to a large extent on the type, condition, and uses made of the watershed. If the watershed is in forest and sparsely inhabited, the chances for contamination are less than where the watershed is inhabited. However, in either case surveys should be made to indicate sources and possible types of contamination and every effort made to eliminate them. As a minimum requirement, the reservoir and as much as possible of the watershed should be fenced against the access of both human beings and stock.

There are rural communities and towns that obtain their water supply from the collection of rainwater from roofs, and individual homes that collect domestic water from both roofs of buildings and from sandstone ledges. These supplies are piped to a cistern and stored for use. In the case of rainwater, it is desirable to run the water through a charcoal filter to remove suspended matter and part of the colloidal material. However, the percentage of bacteria removed with a charcoal filter is very low and such a filter should not be considered as an adequate safeguard to health.

The type of charcoal filter recommended is shown in Figure 12. The water flows upward through this filter. The filter is separated from the inlet by a 1/2-inch screen. Above this screen there is placed about 15 inches of charcoal, ground to 1/4 to 1/2-inch size. Above the charcoal is about an equal depth of gravel or coarse sand separated from the charcoal by a 1/4-inch mesh screen. The total depth of the filter should be about 30 inches.

In general, where surface water has been collected either in a reservoir or from roofs or rock ledges for domestic supply, it is recommended that the water be transported through a filter (sand in the case of surface run-off and charcoal in the case of rainwater) and into a cistern for storage. A satisfactory cistern design is shown in Figure 11 (S.C.S. Handbook, Section 4). The cistern should be concrete or masonry. Do not use steel or lead. When a filter is used, care must be taken to keep the filtering material clean, that is, to check it often, remove the collected materials, and either wash or replace the filtering material.

Filtering alone is not considered a sufficient safeguard against bacteria, and chlorination is recommended for purification of the supply. The amount of chlorine required will depend on the type of water, that is, on the organic content of the water, its hydrogen·ion concentration, presence of carbon dioxide, the time of contact, and other factors. For effective purification frequent analyses of the water are needed to add the correct amount of chlorine for purification. Too much will give the water an objectionable taste and odor. Bleaching powder or Hitest Hypochloride may be used to purify water in cisterns by adding the proper amount of this powder to each filling. However, liquid chlorine has greater advantages and where possible this should be used. Cost of treating water is usually in the neighborhood of 50¢ per million gallons.

Before undertaking the purification of water by filtering or by the use of chemicals, the Department of Health of the State or County should be consulted. Arrangements can usually be made with State or county health authorities for testing water intended for domestic consumption to determine its potability and the kind and degree of possible contamination.

WATER LAWS

The overall laws governing use of water are not uniform in the four States within S.C.S. Region 8. While the development of water for farmstead purposes is of first importance in farming communities, neither legislation nor court control of these developments has often been attempted. However, the right to draw underground water, develop springs, or use surface supplies for farmstead purposes should be safeguarded by compliance with all the legal requirements. The exact requirements to be met should be determined by writing to the official in charge of water rights for the State involved. The official in charge in Colorado, New Mexico, and Utah is the State Engineer; the State Water Commissioner is the official in charge for Arizona.

At present there is an attempt to make uniform laws governing underground water in the States of this Region, and in most States the laws relating to underground water should be considered in a state of change. Specific requirements are best met by writing to the authorized State official who will supply copies of the latest published regulations.

In Utah and in certain areas of New Mexico, well drilling specifications are such as to eliminate loss of water from one aquifer to another or any wastage of water. Under such conditions, permits for well drilling, type of casing allowable, and perforations are covered by rigid rules, and drilling operations are subject to inspection by the State Engineer.

Table VIII

Well and Storage Tank Capacities in Gallons

Diameter of well	2"	3"	4"	5"	6"	8"	10"	12"	
Gallons of water per vertical foot	.16	.37	.6	1.0	1.5	2.6	4.1	6.0	
Diameter of storage tank	2'	3'	4'	5'	6'	7'	8'	9'	10'
Gallons of water per vertical foot	24	53	94	147	212	288	376	477	590

In order to figure the total number of gallons of water in any circular well, cistern, or storage tank, take the quantity given in gallons in Table VIII for one vertical foot of the container and multiply by the total vertical feet of water depth.

COSTS

The costs shown in the succeeding Tables IX to XXIII, inclusive, are average prices quoted by various tradespeople and are intended for estimating purposes only. These prices are f.o.b. the major distributing points.

Table IX

Windmill Towers

Tower Height Feet	FOR MILLS 6- & 8-Foot	10-Foot	12-Foot	14-Foot	16-Foot	20-Foot
27	$ 50.00	$ 53.50	$ 86.00	$ 103.00	$ 122.00	$ -
33	59.50	64.00	95.00	114.00	156.00	-
40	71.00	76.00	115.00	136.00	185.00	428.00
53	-	-	-	-	-	543.00
67	-	-	-	-	-	685.00
80	-	-	-	-	-	860.00

TABLE X. Millheads

6 ft.	$ 41.00
8 "	57.75
10 "	95.50
12 "	162.00
14 "	265.00
16 "	385.00
20 "	900.00

TABLE XI. Deep Well Cylinders (All Brass with Ball Valves)

Inside Diameter Inches	Length Stroke Inches	Top Cap Inches	Cost
1-7/8	8	2	$ 14.50
1-7/8	14	2	16.00
2-1/4	13	2-1/2	21.00
2-1/4	19	2-1/2	23.00
2-3/4	12	3	28.60
2-3/4	18	3	31.00
3-3/4	20	4	62.00
3-3/4	26	4	65.60
4-1/4	18	4-1/2	81.00
4-1/4	24	4-1/2	[illegible]3.50

TABLE XII. Sucker Rods (Hollow Airtite Steel) Galvanized

Price per 100 Feet

Rod No.	Size (In.)	LENGTHS: Random Approx. 20'	18 Ft.	15 Ft.	10 Ft.	5 Ft.
1	5/8	$ 13.50	$ 13.50	$ 15.50	$ 17.50	$ 24.50
2	7/8	20.50	20.50	22.50	26.75	36.50
3	1	30.00	32.00	34.00	37.00	50.50
4	1-1/8	41.00	45.00	46.50	50.50	65.00

TABLE XIII. Storage Tanks for Windmill Towers

No.	Capacity of Wood Tank (Gal.)	1½" Redwood Price	1½" Redwood Weight (Lbs.)	2" Redwood Price	2" Redwood Weight (Lbs.)	Galvanized Steel Tank Capacity (Gal.)	Galvanized Steel Tank Gauge of Steel	Galvanized Steel Tank Price	Galvanized Steel Tank Weight (Lbs.)
1	200	$53.50	275	-	-	248	22	$ 48.50	125
2	660	78.00	500	$ 94.00	600	738	20	77.00	300
3	1280	111.00	750	130.00	900	1424	20	114.00	475
4	2175	-	-	195.00	1200	2440	18	175.00	900

The above prices include a galvanized cover for all tanks.

For the windmill tower to care for the above storage tanks, add about 50 percent to the prices on Table I for the small tank, 75 percent for tank No. 2, 90 percent for tank No. 3, and 100 percent for tank No. 4.

The height to the bottom of the tank is the height of the windmill tower less 13 feet for tank No. 1, less 19 feet for tank No. 2, less 26 feet for tank No. 3, and the height of the tower less 33 feet for tank No. 4.

TABLE XIV. Approximate Cost of Galvanized Steel Tank Towers

Height (Ft.)	For Tank Diameter 6' Depth 6' Or Less	For Tank Diameter 7' Depth 7' Or Less	For Tank Diameter 8' Depth 8' Or Less	For Tank Diameter 9' Depth 9' Or Less	For Tank Diameter 10' Depth 10' Or Less	For Tank Diameter 12' Depth 12' Or Less
10	$ 66.00	$ 74.00	$ 85.50	$ 144.00	$ 167.00	$ 209.00
20	97.00	111.00	134.50	199.00	247.00	297.00
30	135.00	150.00	186.50	273.00	334.00	418.00
40	173.00	192.00	242.00	353.00	415.00	508.00
50	221.00	253.00	310.50	433.00	497.00	605.00
60	280.00	316.00	385.50	513.00	586.00	713.00

TABLE XV. Approximate Cost of Tank Joists and Flooring (Just fit to tank)

Diameter of Tank Ft.	Wood Joists	Steel Joists	Floor
6	$ 15.75	$ 36.00	$ 8.75
7	22.75	54.00	12.25
8	29.00	63.50	15.75
9	37.00	97.00	19.25
10	51.50	105.00	25 00
12	73.50	210.00	35.00

TABLE XVI. Approximate Cost of Extension Platforms and Railings for Steel Tower (Platform to hold tank and provide a walkway around the tank)

Diameter of Tank Ft.	Wood Platform	Steel Platform	Hand Railing
6	$ 89.00	$ 118.00	$ 28.50
7	102.00	157.50	29.50
8	120.00	172.00	30.50
9	149.00	223.00	31.50
10	197.00	236.00	32.75
12	270.00	380.00	34.50

TABLE XVII. Approximate Prices of Steel Tanks

(Prices given are for 20-gauge tanks; for 18-gauge add 30%; for 16-gauge add 60%.)

Diameter Ft.	Height Ft.	Price	Diameter Ft.	Height Ft.	Price
5	4	$ 47.20	8	8	$ 139.30
5	5	56.00	8	10	165.00
5	6	64.80	9	4	103.40
5	7	73.60	9	5	118.10
5	8	84.20	9	6	132.60
5	10	100.00	9	7	147.30
6	4	56.60	9	8	161.90
6	5	66.60	9	10	191.10
6	6	76.50	10	4	120.00
6	7	86.50	10	5	135.70
6	8	96.40	10	6	151.60
6	10	116.30	10	7	167.30
7	4	72.20	10	8	183.20
7	5	83.40	10	10	214.50
7	6	94.60	12	4	156.00
7	7	106.00	12	5	175.50
7	8	117.30	12	6	195.00
7	10	139.90	12	7	214.50
8	4	87.80	12	8	234.00
8	5	100.70	12	10	273.00
8	6	113.50	12	12	321.80
8	7	126.40			

Prices of Wood Storage Tanks. Wood storage tanks with 2" staves will cost about 40% more than the 20-gauge metal tanks listed in Table XVII; about 10% more than the 18-gauge metal tanks; and about 15% less than the 16-gauge metal tanks. Wooden storage tanks with 1-1/2" staves will cost about the same as the 20-gauge metal tanks listed in Table XVII.

Corrugated Supply Tanks with Covers. Corrugated supply tanks with covers will cost about the same as the 20-gauge steel tanks listed in Table XVII. The smaller tanks are made of 22-gauge metal in the lower part and 24-gauge metal in the upper part; the larger tanks of 18-gauge metal in the bottom and 20-gauge metal in the top. For equal gauges, corrugated metal tanks are stronger than plain steel.

TABLE XVIII. Approximate Prices of Cone Covers for Tanks

Diameter Ft.	Price
4	$ 16.30
5	21.10
6	27.20
7	34.00
8	41.60
9	50.20
10	59.60
12	81.40

TABLE XIX. Approximate Costs Pump Jacks Only

Capacity Gallons Per 8 Hrs.	DEPTH (In Feet)						
	25	50	75	100	200	300	400
480	$ 26.00	$ 26.00	$ 26.00	$ 26.00	$ 26.00	$ 26.00	$ 65.00
960	"	"	"	"	"	"	65.00
1440	"	"	"	"	"	"	65.00
1920	"	"	"	"	"	65.00	65.00
2400	"	"	"	"	40.00	65.00	65.00
2880	"	"	"	"	40.00	65.00	65.00
3360	"	"	"	"	40.00	65.00	160.00
3840	"	"	"	"	40.00	65.00	160.00
4320	"	"	"	65.00	40.00	65.00	160.00
4800	"	"	"	65.00	65.00	160.00	160.00
7200	"	"	"	65.00	160 00	160.00	160.00
9600	"	"	"	65.00	160.00	160.00	205.00
12000	40.00	65.00	65.00	160.00	160.00	160.00	225.00

TABLE XX. Approximate Prices of
Electric Motors

H. P.	Price
1/4	$ 10.00
1/3	14.00
1/2	25.00
3/4	32.00
1	41.00
2	71.00
3	93.00
5	151.00
7-1/2	177.00

TABLE XXI. Approximate Prices of
Gasoline Motors
(Air cooled to 1½ H.P. Hopper Cooled from 1½ H.P. to 10 H.P.)

H. P.	Price
3/4	$ 50.00
1	50.00
1-1/2	60.00
2	75.00
3	95.00
4	130.00
5	130.00
7-1/2	225.00
10	295.00

TABLE XXII. Approximate Prices of
Well Casing (Standard Pipe)
(Less than carload lots)

Size (In.)	Price per 100 Feet
3	$ 50.58
3-1/2	64.97
4	76.98
5	83.25
6	108.00
8	149.50
10	238.19
12	300.00

TABLE XXIII. Approximate Prices of Drain Tile (Less than Carload Lots)

Size (In.)	Price per Foot
4	$ .12
6	.19
8	.30
10	.45

SUGGESTED PROCEDURE

The following steps in developing farmstead Water Facilities Dockets are suggested:

1. Obtain standard application (WF 4, Rev. Jan. 1941).
2. Furnish S.C.S. copy of application (2 copies if assistance requested).
3. Investigate application for eligibility and feasibility.
4. Make reply to applicant (copy to S.C.S.), using regular form, WF 11.
5. If S.C.S. is to be called in, make request to Area Conservationist in writing.
6. Be sure reasonable chance exists to develop adequate water.
7. Check on rights to develop water as requested by applicant.
8. Check on available security.
9. Proceed with preparation of docket, including estimates and PCO's, if required.
10. In case of deep wells, observe State regulations regarding licensing of drillers and permits to drill.
11. Require driller to determine quantity of water, at least by bailing test, and record depth to static water and amount of drawdown.
12. Require driller to furnish State offices with logs of drilled wells.
13. Observe State health regulations regarding quality of water before installing equipment.
14. Furnish S.C.S. with copy of completed 656-A.

REFERENCES

Generous use has been made of material compiled by other agencies. We suggest a widespread distribution of Farmers Bulletin No. 1859 which may be obtained through regular channels. An effort is being made to place two copies each of Sections 4 and 5 of the S.C.S. Engineering Handbook in each F.S.A. Regional Office. It is suggested that excerpts be made by those offices of the material which is adaptable to their various problems.

Section 4 is entitled "Sanitary Standards for Rural Water Supplies and Systems." Section 5 is entitled "Sanitary Standards for Disposal of Sewage and Domestic Wastes in Rural Areas."

The following specific references are made to published material which is recommended to all personnel engaged in planning farmstead facilities:

<u>Farmers Bulletin No. 1859</u>

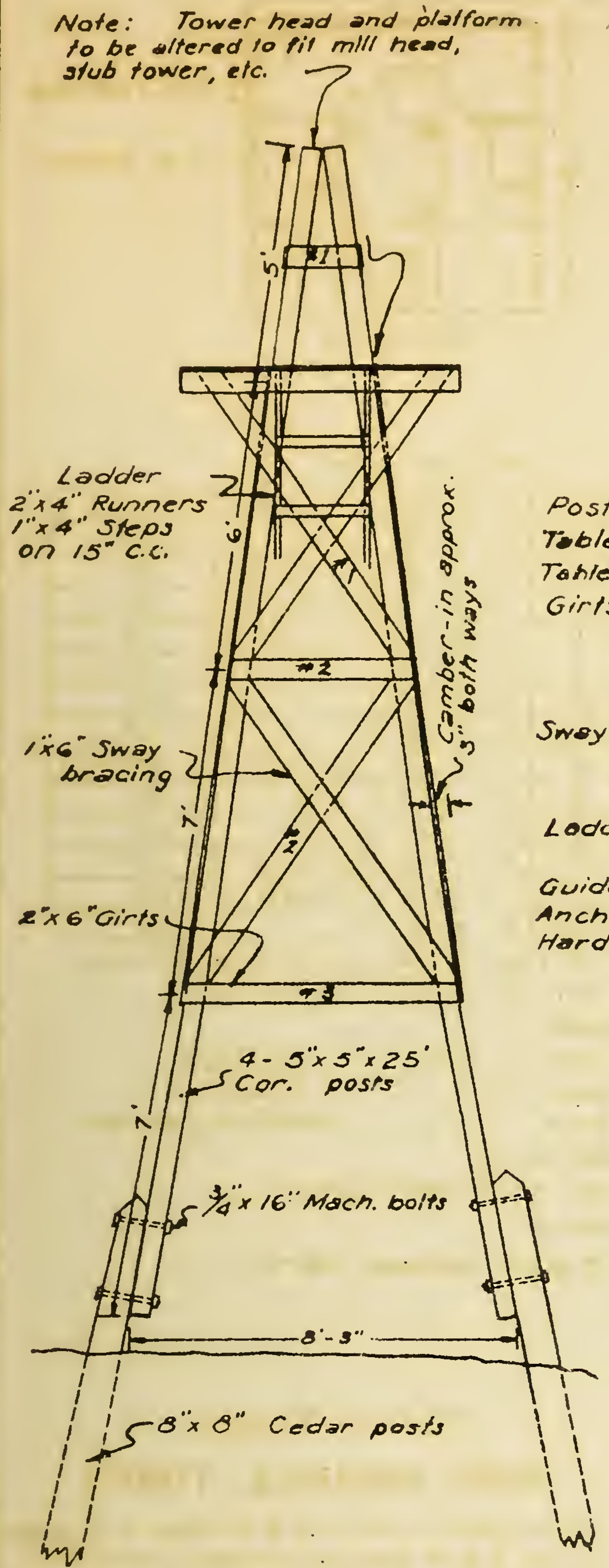
Wells	Pages 13 to 18, incl.
Springs	" 23 to 29, "
Impounding Reservoirs	" 49 to 65, "

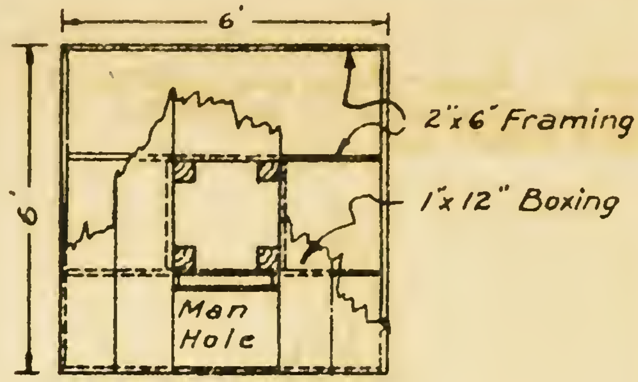
<u>Engineering Handbook, Sec. 4</u>

Selecting drinking water supplies	" 3 to 5 "
Well supplies	" 6 to 11, "
Drilled wells	" 14 to 18, "
Pumping equipment	" 20 to 26, "
Quality and protection of small water supplies	" 33

<u>Engineering Handbook, Sec. 5</u>

This material is submitted because of its value in showing methods available for protecting farmstead water supplies from one of the most likely sources of contamination.





Platform

Materials

	Pcs.	Dimen.	Grade	Bd. Ft.
Posts	4	5"x5"x25'		208
Table Fr'm.	6	2"x6"x6'	#1 S4S	36
Table Top	6	1"x12"x 6'	#2 Boxing	36
Girts #1	6	2"x6"x2'	#1 S4S	12
#2	4	2"x6"x 4'	"	16
#3	4	2"x6"x6'	"	24
Sways #1	4	1"x6"x16'	#1 Rgh.	32
#2	4	1"x6"x18'	"	34
Ladder	2	2"x4"x20'	#2 S4S	27
	2	1"x6"x16'	#1 S4S	16
Guides	2	2"x6"x6'		12

Anchors 4 Cedar Posts 8" top 8' long

Hardware 8 3/4" x 16" Mach. bolts

Nails

8d 2 lbs. Ladder

16d 6 " Sways

20d 8 " Girts & Ladder

Washers

3/4" Flat wr't 3 Lbs.

Paint

2½ gals. mixed, barn

25 FT. TOWER

WOOD WINDMILL TOWER

This tower is for 12 & 14 foot mill heads. For 6, 8 & 10 foot mill heads use 4"x4" corner posts. For 16 & 18 foot mill heads use 6"x6" corner posts.

Figure 1

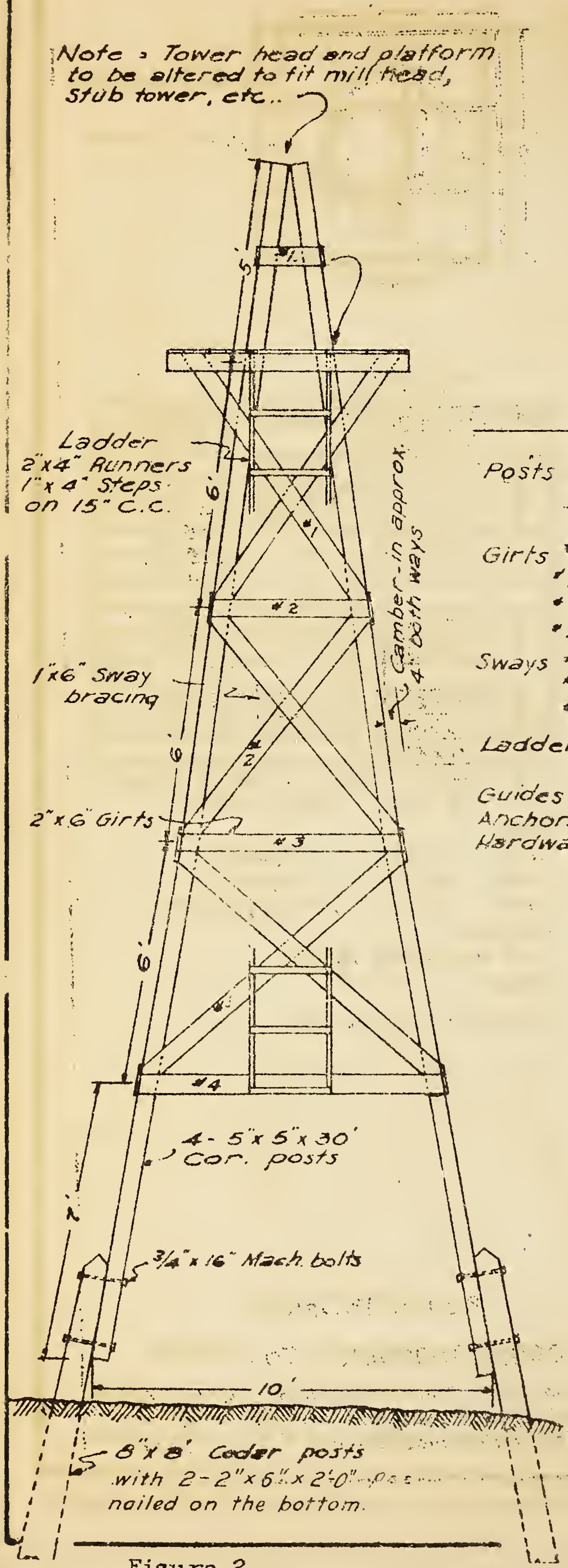
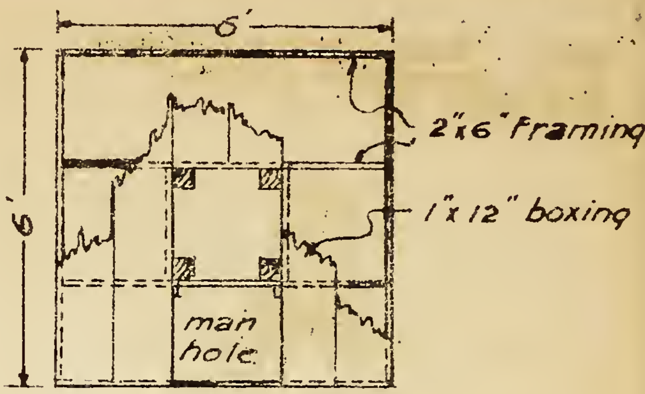


Figure 2



Platform

Materials

	Pcs	Dimen	Grade	FBM
Posts	4	5"x5"x30'		250
	6	2"x6"-6'	#1 S4S	36
	6	1"x12"x6'	#2 Boxing	36
Girts #1	6	2"x6"x2'	#1 S4S	12
#2	4	2"x6"x4'	"	16
#3	4	2"x6"x6'	"	24
#4	4	2"x6"x8'	"	32
Sways #1	4	1"x6"x16'	#1 Rgh	32
#2	4	1"x6"x16'	"	32
#3	4	1"x6"x18	"	36
Ladder	2	2"x4"x20	#2 S4S	27
	2	1"x6"x16'	#1 S4S	16
Guides	2	2"x6"-6'		12

Anchors 4 Cedar Posts 8" top 8' long
Hardware 8 3/4"x16" Mach bolts

Nails

8d 3 lbs Ladder
16d 8 " Sways
20d 10 " Girts & Ladder

Washers

3/4" Flat wrt 3 Lbs

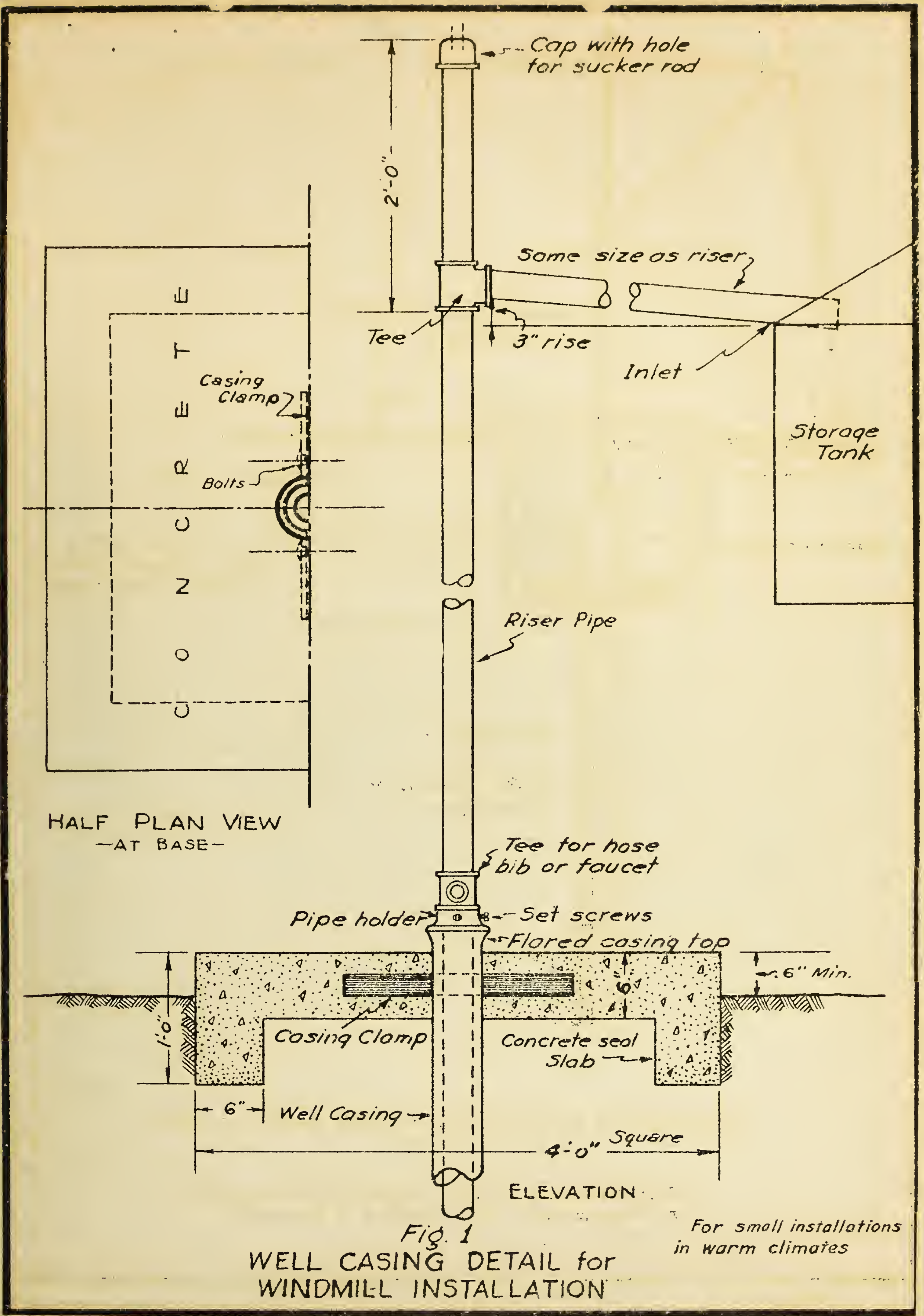
Paint

3 gals. mixed, barn

30 Ft. Tower

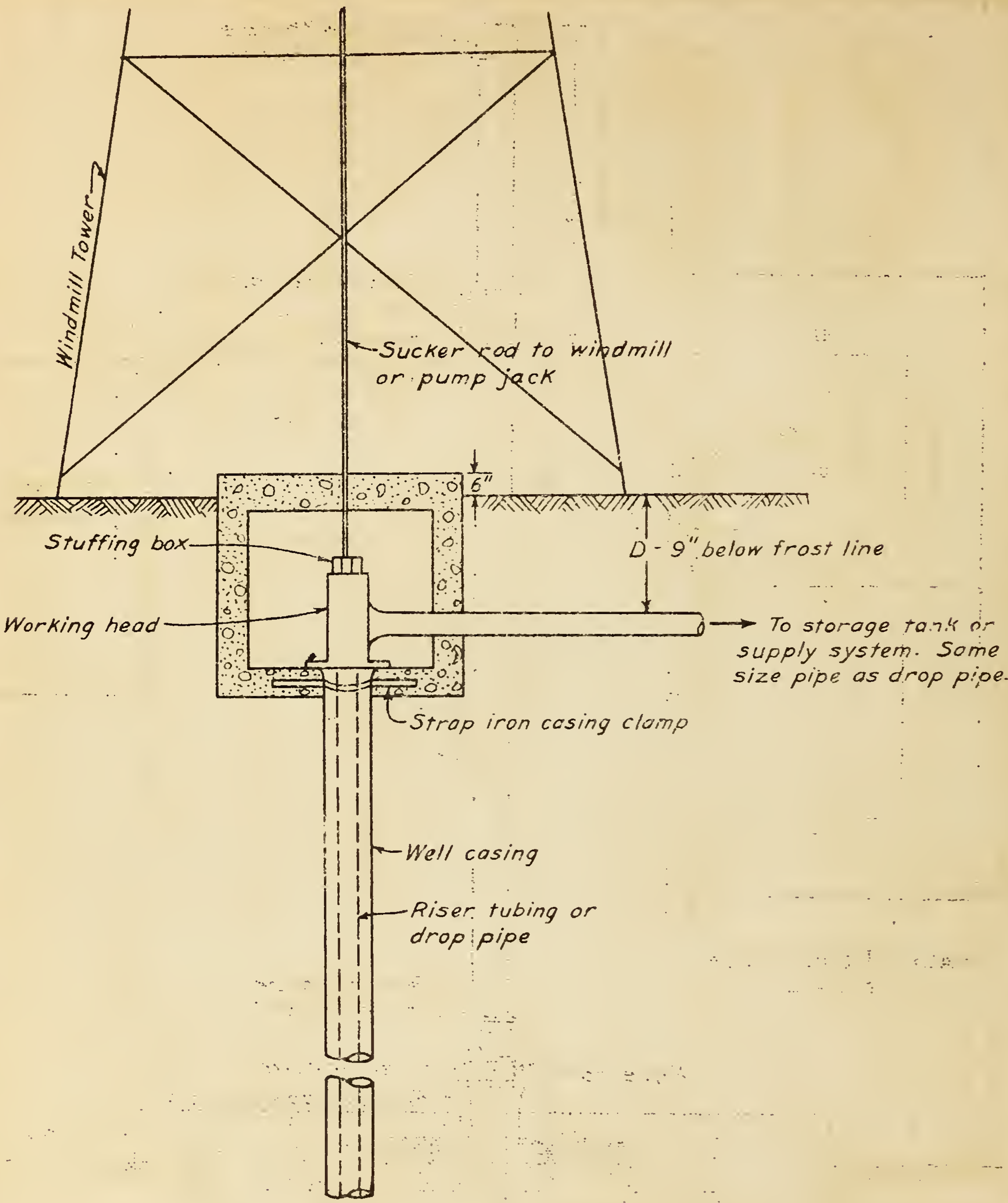
WOOD WIND MILL TOWER

This tower is for 12 & 14 foot mill heads. For 6, 8 & 10 foot mill heads use 4"x4" corner posts. For 16 & 18 foot mill heads use 6"x6" corner posts.



Cap with hole for sucker rod
2'-0"
Same size as riser
Tee
3" rise
Inlet
Storage Tank
CONCRETE
Casing Clamp
Bolts
HALF PLAN VIEW
—AT BASE—
Riser Pipe
Tee for hose bib or faucet
Pipe holder
Set screws
Flared casing top
6" Min.
6"
1'-0"
Casing Clamp
Concrete seal Slab
6"
Well Casing
4'-0" Square
ELEVATION
Fig. 1
WELL CASING DETAIL for WINDMILL INSTALLATION
For small installations in warm climates

Figure 3

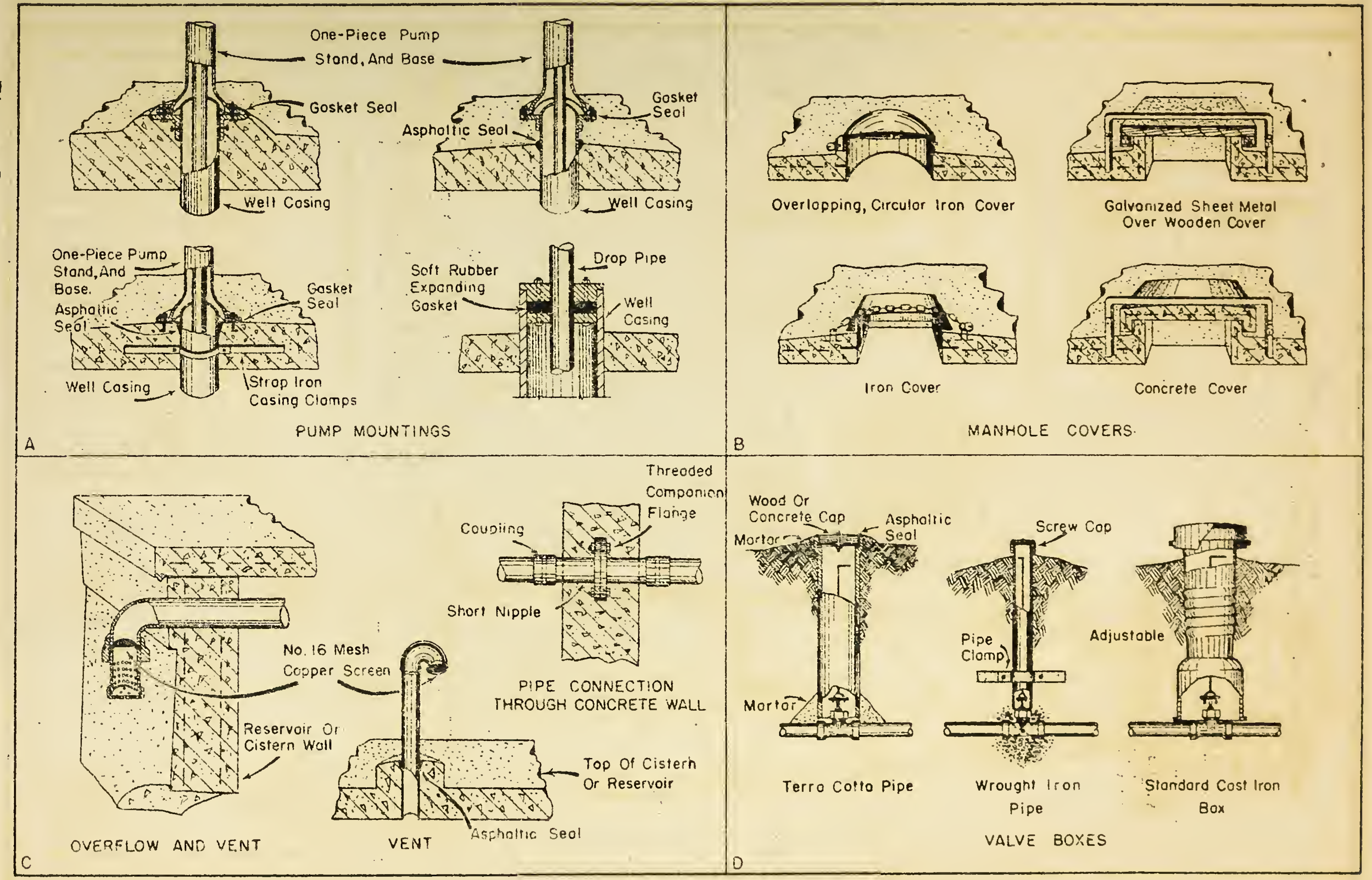


Combined air chamber and working head for wells in cold climates.

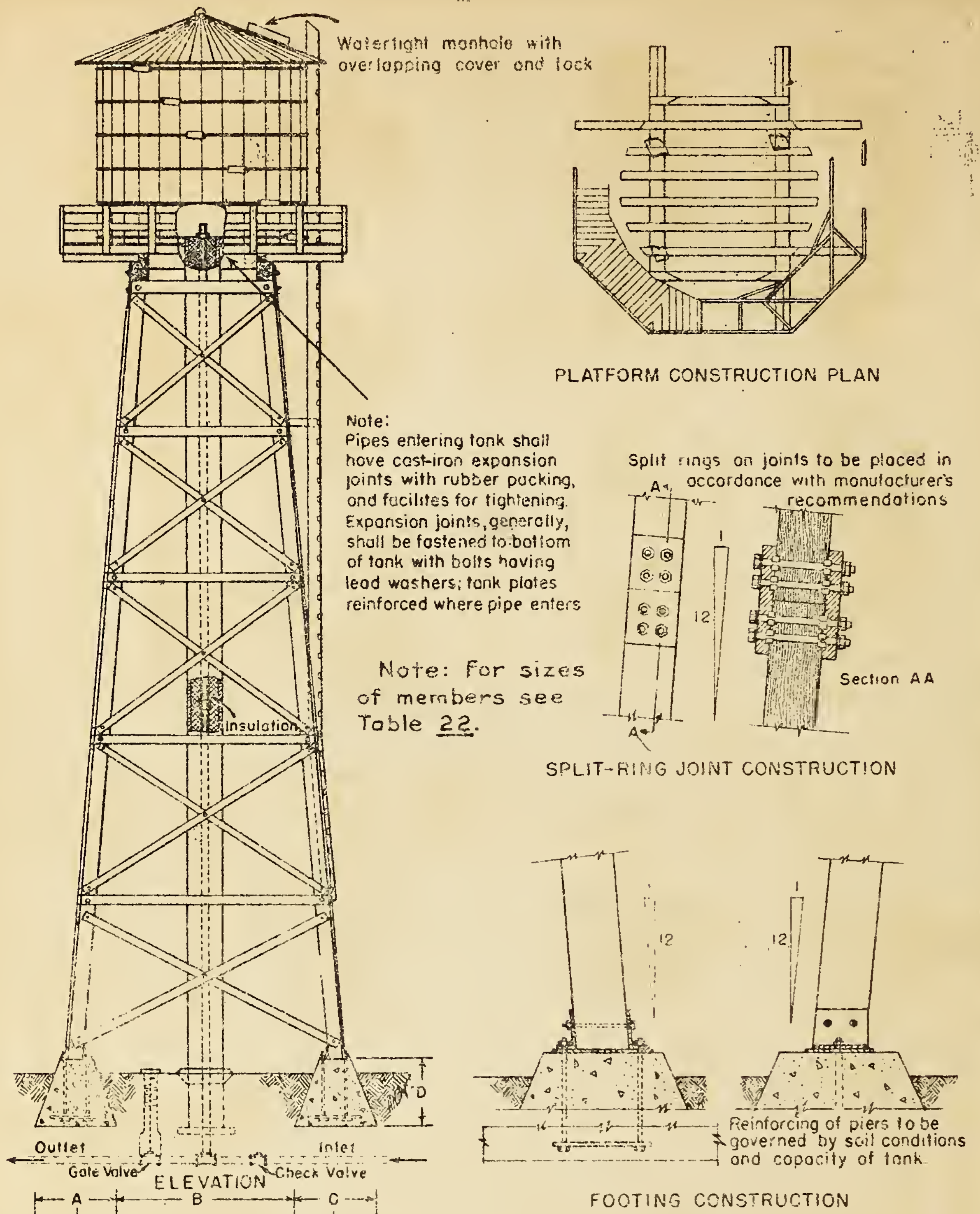
This type installation will require only one pipe to storage tank. (See Figure 6 & Page 39).

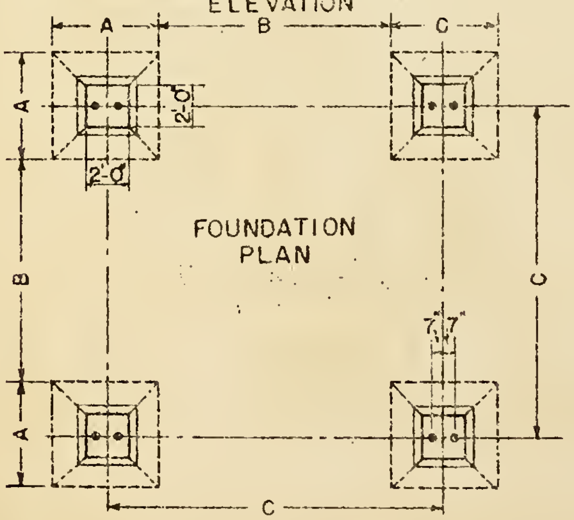
Figure 4

Figure 5



Proper pump mountings, valve boxes, vents, and manhole covers.





NOTE - Piers based on soil bearing 1500# per sq foot

DIMENSIONS FOR FOUNDATION PLAN VARIOUS HEIGHTS & 10,000 GAL. TANK				
HEIGHT TANK	A	B	C	D
30'- 0"	4'- 0"	8'- 5"	12'- 5"	3'- 6"
40'- 0"	4'- 2"	9'- 11"	14'- 1"	3'- 6"
50'- 0"	4'- 6"	11"- 3"	15'- 9"	4'- 0"

Figure 6. – Proper design for elevated tank on wooden tower.

Dimensions of Lumber

Size of Tank	Height	Floor Joists		Flooring*	Column Cap	Column Legs	Bracing	
		Size	Spacing				Struts	Sway
Ft.	Ft.	In.	In.	In.	In.	In.	In.	In.
6D, 6H	10-30	3x 6	10	1 x 6	4x 6	4x4	2x6	2x6
7D, 7H	10-30	3x 6	12	1 x 6	4x10	4x4	2x6	2x6
8D, 8H	10-30	3x 8	14	1 x 6	4x14	5x5	2x6	2x6
8D, 8H	35-50	3x 8	14	1 x 6	4x14	6x6	2x8	2x8
9D, 9H	10-30	3x 8	12	$1\frac{1}{2}$ x 6	6x14	5x5	3x6	2x8
9D, 9H	35-50	3x 8	12	$1\frac{1}{2}$ x 6	6x14	6x6	3x6	2x8
10D, 10H	10-50	3x12	12	$1\frac{1}{2}$ x 6	8x14	6x6	3x6	2x8
12D, 12H	10-50	4x12	10	$1\frac{1}{2}$ x 6	10x18	7x7	3x6	2x8

* Flooring to have 1/2" space between each board and two lines of 1/2" holes, 6" centers, in each board, staggered, to provide drains. Bottom of tank and top of floor to be asphalt painted.

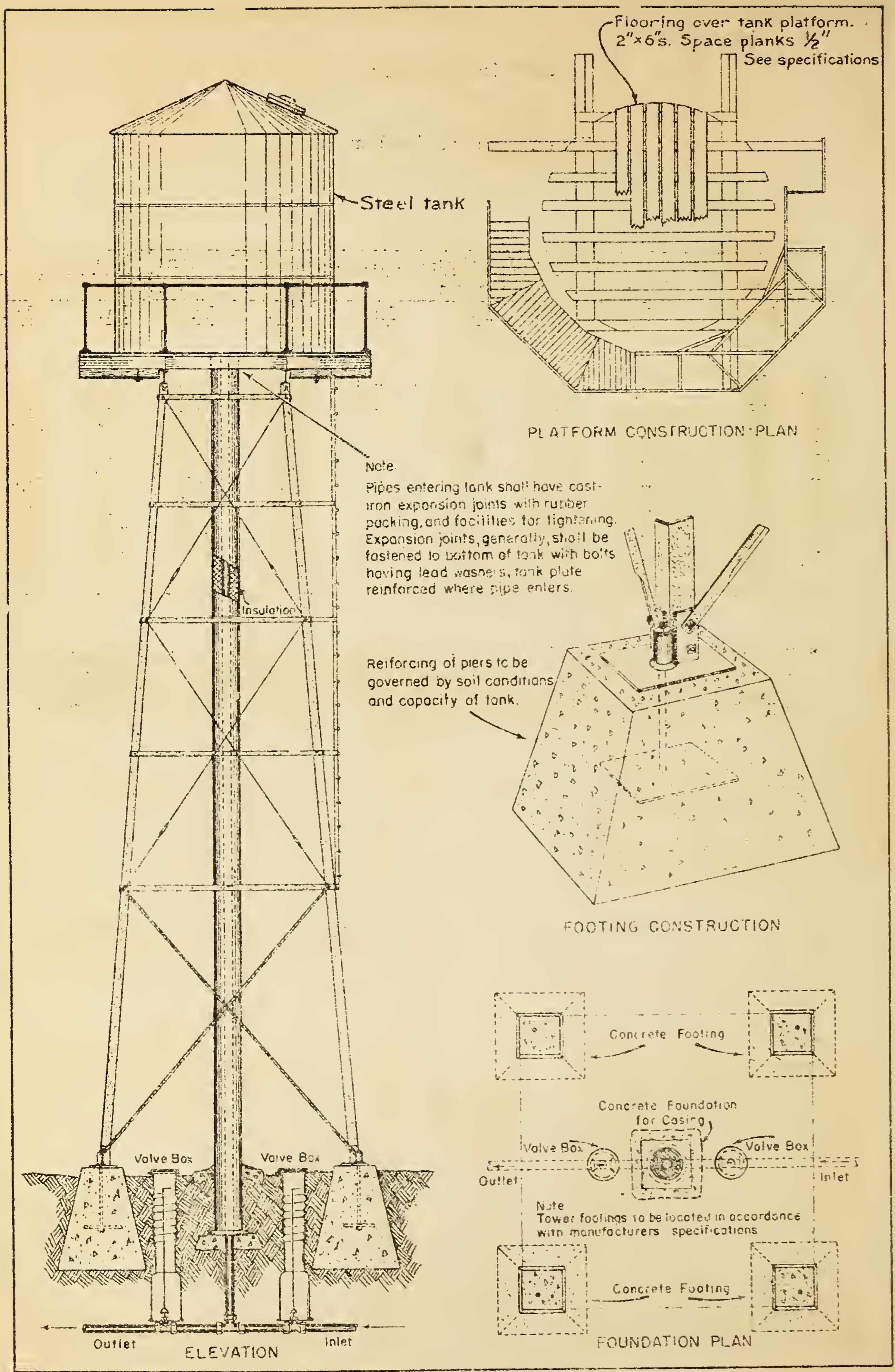
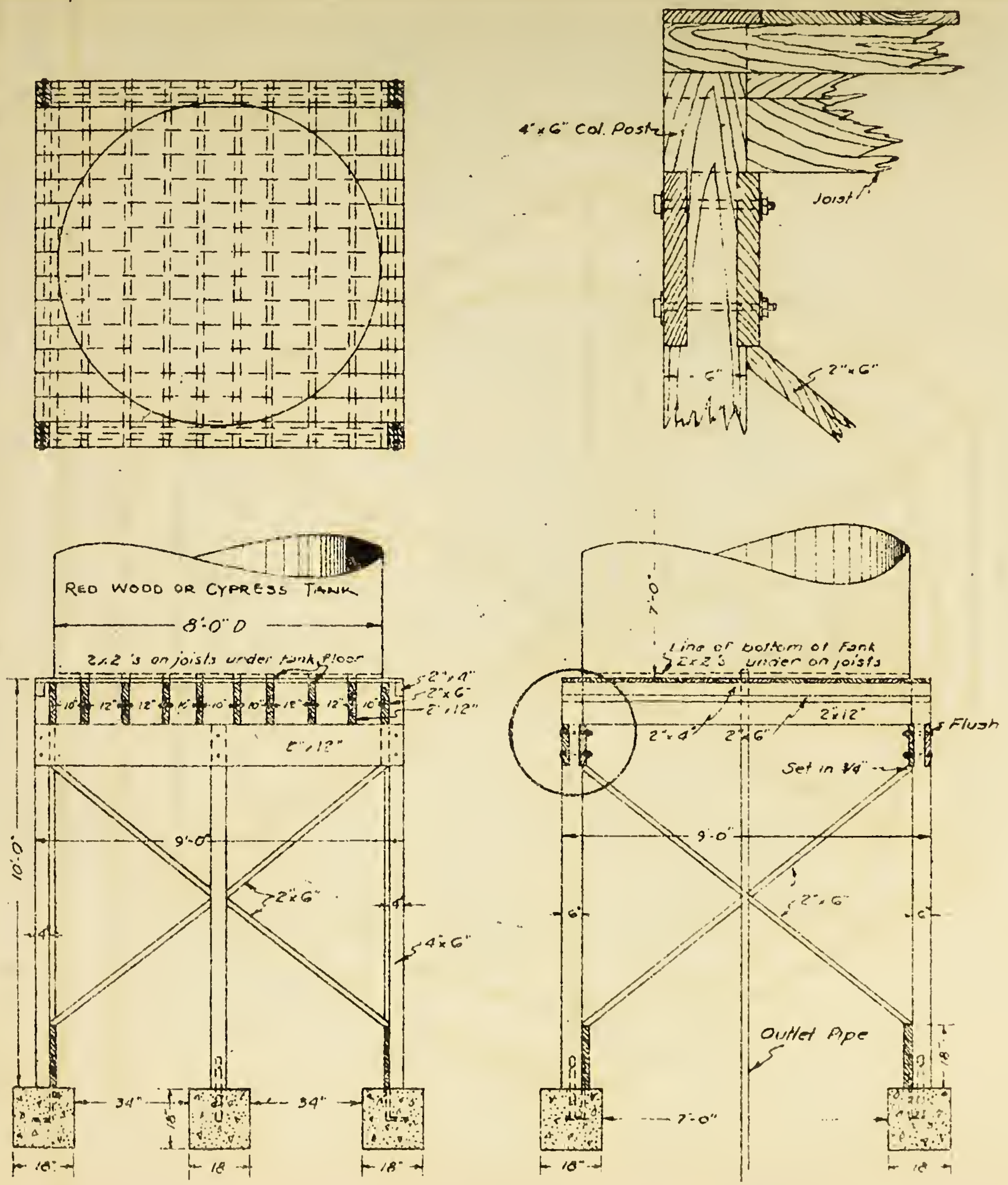


Figure 7. – Typical design for elevated wooden tank on steel tower.



BILL OF MATERIALS

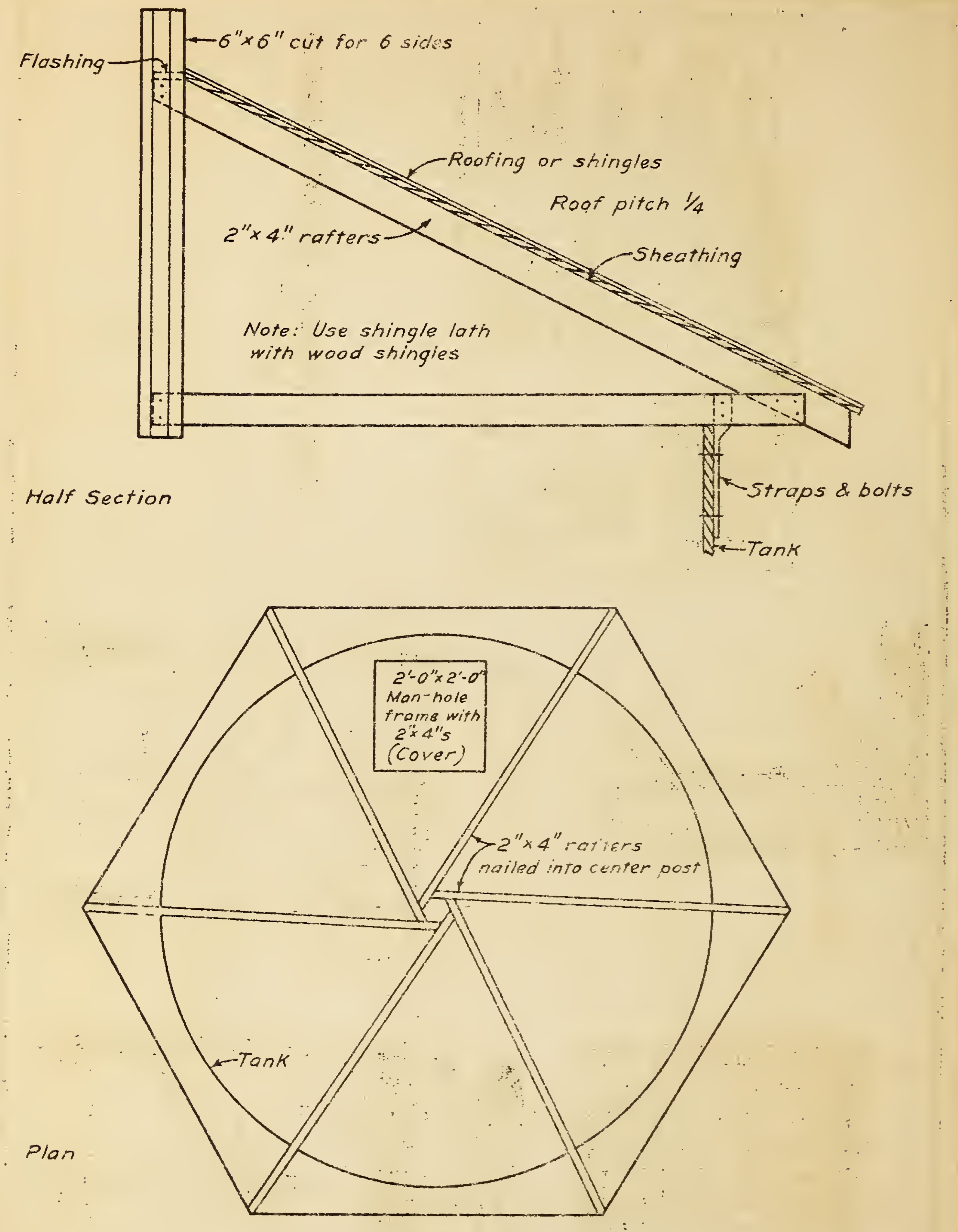
UNIT	SIZE	F.B.M.	GRADE & MATERIALS	USE
6	4"x6"x10'	120	No. 1 S4S. Fir or Yellow Pine	Column
6	2x12'x18'	216	" " " " "	Joists
2	2"x6"x20'	40	" " " " "	" & Blocking
4	2"x6"x20'	80	" " " " "	Cross-Bracing
2	2"x4"x18'	24	" " " " "	Cover Support
1	2"x4"x14'	19	" " " " "	Blocking
8	1"x8"x18'	96	" " " " "	Flooring
12	5/8"x9"		Machine Bolts	Outside Girders
6	1/2"x5"		" "	Anchor Bolts
6	1/4"x2"x2'		Flat Steel	Anchors
3 lbs.	5/8"		Flat Wrt. Washers	
1 lb	1/2"		" " "	
8 lb	16 D		Box Nails	Bracing & Toe Nailing
2 lb	8 D		" "	Flooring
84 sq. ft			Roofing 75#	Roof
3 1/2 gals			Paint	Covering
5 Sacks			Cement	Footing
1 Cu. Yd.			Sand & Gravel	"

NOTE: 2x2's Under Tank Floor not included in bill of material

TANK TOWER 80 BBL. CAPACITY

Specification "D"

Figure 8



Suggested Fabricated Top for Wood Storage Tank

Figure 9

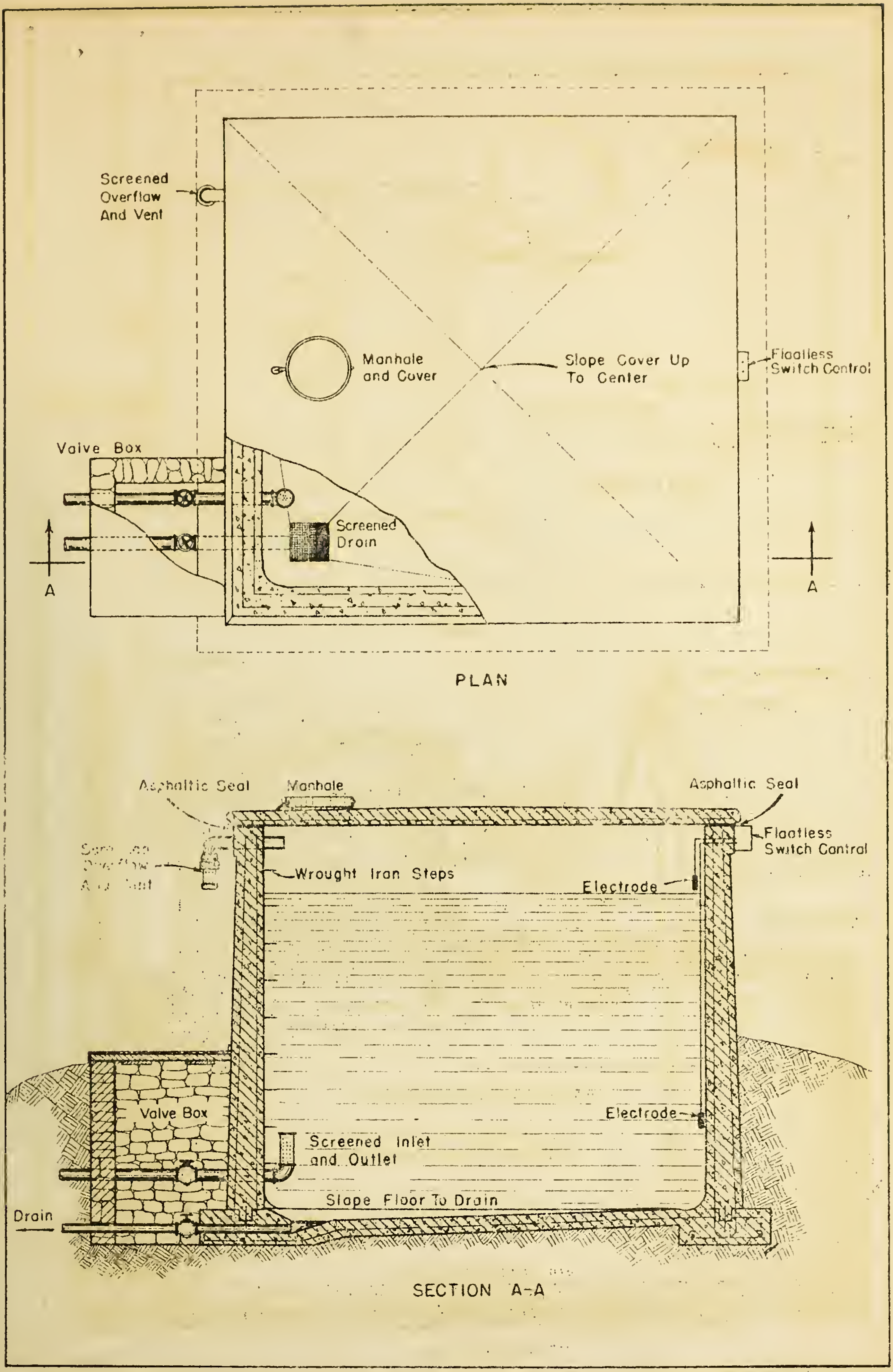


Figure 10 – Proper construction for concrete reservoir.

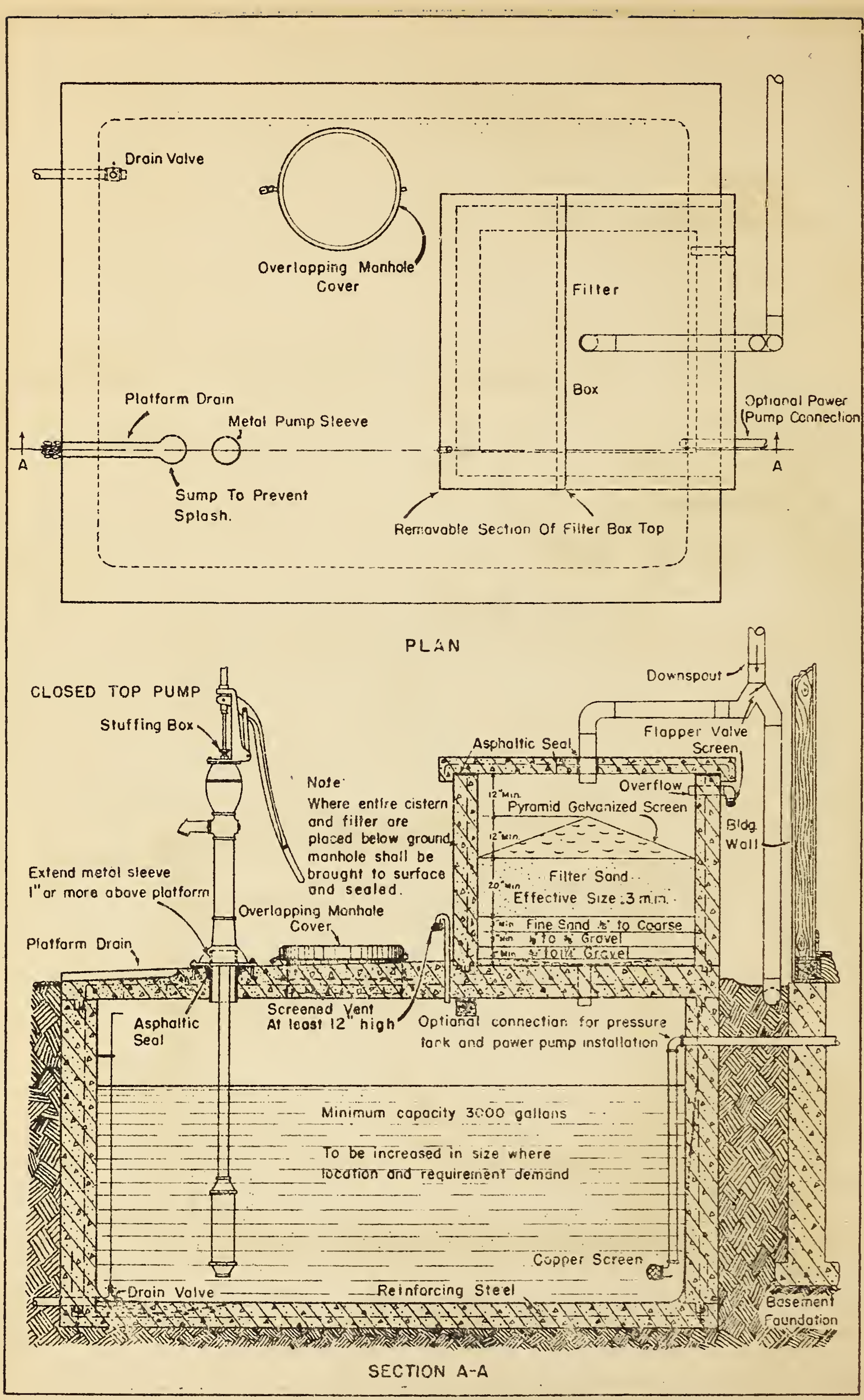


Figure 11 – Properly designed cistern showing optional pump installations.

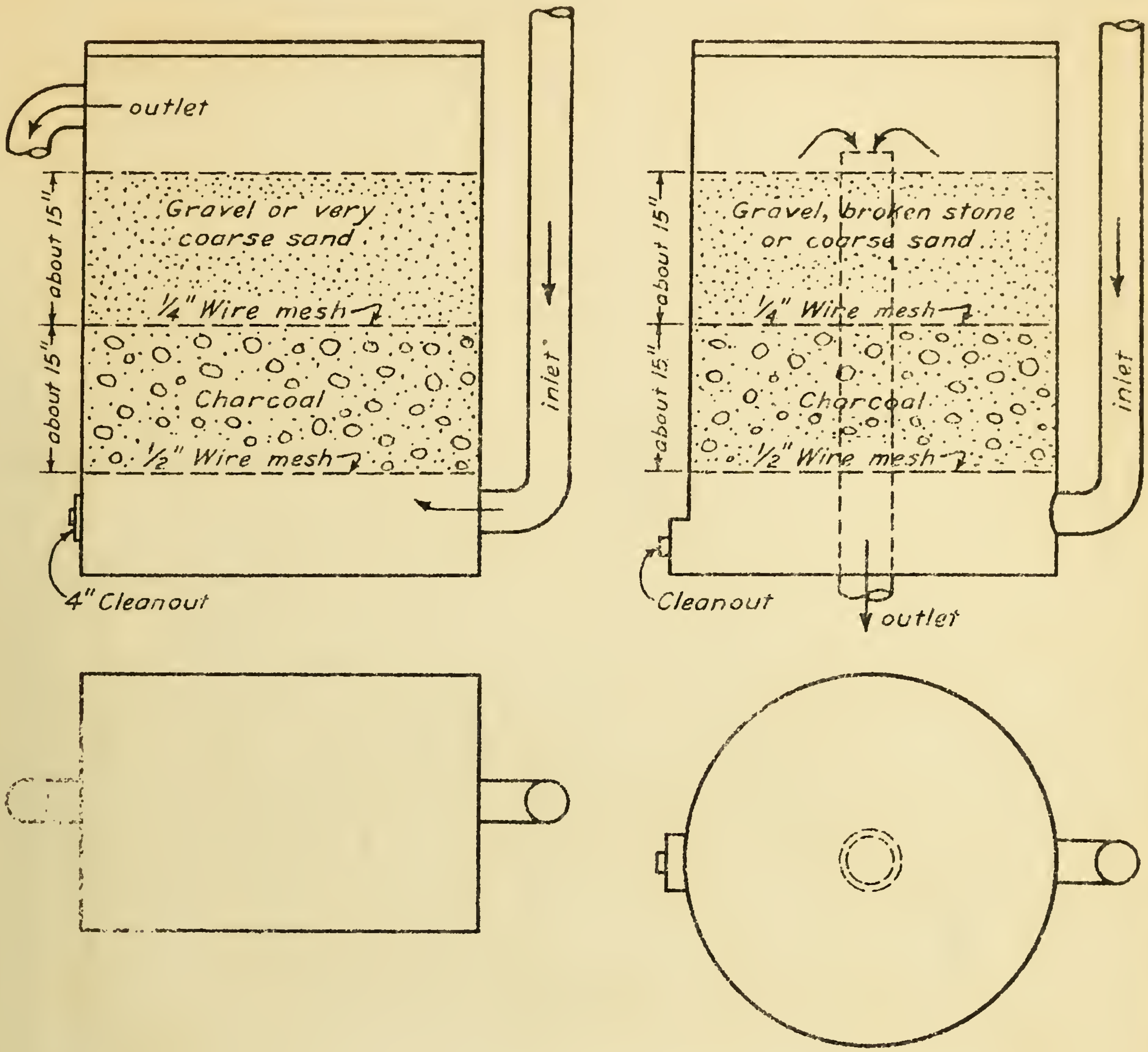


Diagram of Charcoal Water Filter

(Taken from Water Supply Engineering, Page 707)

Figure 12